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The Past, Present and Projected Demands on Manitoba's Freshwater Fish Resources

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ABSTRACT

This report briefly reviews the history of the exploitation [illegible] freshwater fish resources in Manitoba. Past trends in demands, particularly by commercial and recreational fishermen, on fish resources, are examined and projected into the future to the year 2000. This analysis indicates that if current trends continue over the next two decades (1980's and 1990's), demands will outstrip the supply of the prime species of fish (e.g. lake whitefish, walleye, sauger, northern pike and lake trout) by the year 2000. The most significant growth in demand will likely be realized in the angling population.

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PART I

INTRODUCTION

As early as the late 1800's, Manitoba's freshwater fish resources have been of significant value to the provincial economy. Initial exploitation of the fish resources, for purposes other than limited local consumption, was by the commercial fishing industry. Although the level of commercial exploitation has grown over the years, it is being supplanted by a steady increase in recreational fishing. Demands on the fish resource base have also been heightened in recent years by a growing network of roads. Many waterbodies, particularly in the north, that were previously either untapped or lightly exploited, are now being intensively fished. The constant growth in the angling public and the continued demands by other resource users for increased harvests and improved economic returns necessitates a greater understanding on the part of fishery managers of the available fish resources and the ultimate impact of current user trends on these resources. Such knowledge is vital to the formulation of effective management measures, as well as policies.

A synopsis of the past, present and projected status of Manitoba's fish resources was first prepared in 1977, but was not printed. The current report represents, with some modification, an update of the 1977 synopsis. As before, the present report was compiled to provide a general overview of freshwater fish yield potential and the distribution of that potential within Manitoba waters.

The present report has been divided into several sections.

The first (Part II) deals with the identification of the various ways fish resources are utilized, some basic assumptions in the formulation of future demands on the fish resource base, and finally the types of information compiled and the methods used to interpret that information. The second section (Part III) considers the past and present trends and various historical aspects of Manitoba's fishery. The next section (Part IV) consists of estimates of the total available fish supplies; i.e. the freshwater fish resource base in Manitoba. The fourth section (Part V) presents estimates of future harvest demands which may be imposed on this fish resource. The final section (Part VI) provides some concluding remarks and recommendations.

PART II

METHODS

Fish resources in Manitoba are utilized in a variety of ways. These uses may be categorized into several distinct groups. The two most prominent categories are commercial and recreational fisheries. Past and present commercial fishing gear used in Manitoba have been almost exclusively gillnets, although other gear types, such as trap nets, pound nets, and set lines, have been or are used to a limited extent. Recreational fishing may consist of angling, spearfishing, bowfishing or dipnetting, but most recreational fishing relates to angling. (Dipnetting is allowed for rough fish only, eg. suckers, carp, etc.). Non-consumptive recreational uses of fish resources in Manitoba, such as viewing, are presently not a major factor. Other uses include domestic or subsistence fishing, bait fishing and collection of fish for scientific purposes. Fish culture or the artificial propagation of fish is also a form of utilization of fish resources in that natural fish stocks are used to obtain fertilized eggs to supply fish hatcheries. Aquaculture or the "controlled" rearing of fish cannot be classified as a use of natural fish stocks and therefore has not been considered in any detail in this report. It is important to recognize, however, that aquaculture provides an alternative source of fish if demands cannot be met from existing natural sources. In Manitoba, aquaculture is carried out basically for the commercial or personal production of rainbow trout (*Salmo gairdneri*) from natural ponds or man-made dugouts.

In order to project future demands on freshwater fish resources in Manitoba, several baseline assumptions were made. These assumptions generally depicted a situation of normalcy and formed the base for prediction of future exploitation of fish resources.

The first assumption is that the utilization of fish resources, as with other resources, is in large part linked to human population changes. Since much of the commercial fish produced in Manitoba is exported to foreign markets and since sport fishermen from elsewhere come to Manitoba, fisheries exploitation is dependant upon outside population growth as well as internal population pressures. Increasing populations in Manitoba and externally will continue to impose increased pressure on the freshwater fish resources in Manitoba in future years.

A second assumption is that within the foreseeable future the existing or improved modes of transportation will still be available, despite rising energy costs, to carry fish resources to people or vice versa. In the same view, the network of roads, railways, air and other transportation links that have been developed in the past will continue to expand and open up northern areas of Manitoba as yet largely inaccessible to the majority of people. Improved access will have major impact on the exploitation of northern fish resources.

A third assumption is that present sociological trends, which include the change from a subsistence type of economy to one oriented to skilled wage labour, will continue. This change brings with it an increase in leisure time available to the general populace and consequently a greater demand for recreational pursuits. Concomitant with the increased earning power of more and more people, it is assumed that the total amount of disposable income will increase. It therefore may be reasonable to expect the continuance of an accelerating rate of growth in recreational activities such as sport fishing.

A final assumption is that no innovative, effective technology will be developed in the immediate or foreseeable future to substantially increase the quantity of fish available for harvest from Manitoba waters. Because of Manitoba's rigorous winter climate, the artifical culture of fish from natural waters is presently possible only on a limited scale. In order to increase this potential, expensive technology will be necessary and the cost-benefit ratio of such developments may be so high as to render them economically non-viable, at least within the foreseeable future. The utilization of Manitoba's fish resource potential must therefore depend upon the existing fish supply, as has been the case in the past.

Information compiled within this report was gathered from various sources. Some information came from unpublished material, while the bulk of the data was from Manuscript Reports of the Manitoba Department of Natural Resources. Appendix I gives a listing of source documents from which information was taken. Each document listed in Appendix I was given a number. The source of various bits of information presented in this report can be found by cross-referencing the document numbers given in the tables or other appendices to the source document numbers listed in Appendix I.

With the exception of the three major lakes (lakes Winnipeg, Winnipegosis and Manitoba) and some other lakes, there has never been a detailed inventory of water surface areas in Manitoba. Sunde (1965) and Schlick (1977) list the areas for a number of northern Manitoba lakes, but these tallies are far from complete. Estimates of number of lakes and total water area (excluding rivers) for non-registered or unsurveyed waterbodies were tallied and categorized as to size by using maps with a scale of 1:250,000.

To obtain an estimate of surface water area in Manitoba, a grid template depicting three different areal sizes was made for use with 1:250,000 scale maps. The template areas were 500, 1000 and 5000 hectares (Fig. 1). Four categories of lake area were considered; these were:

>5000 ha (>12,350 ac.)
1000-5000 ha (2460 - 12,350 ac.)
500-1000 ha (1220 - 2460 ac.)
<500 ha (<1220 ac.)

This template was then used to classify each readily definable lake from 1:250,000 scale map sheets of Manitoba into the above size categories. The classification of most lakes 1000 ha or larger into their appropriate size categories was simplified since their surface areas were already known. During this classification process, the following approximate average sizes of lakes within each size category were determined:

Lake size class (ha)	Average area (ha)
>5000	12,000
1000-5000	3,000
500-1000	700
<500	80

These averages in combination with the tallies in each size category were then used to estimate the total lake surface area in Manitoba.

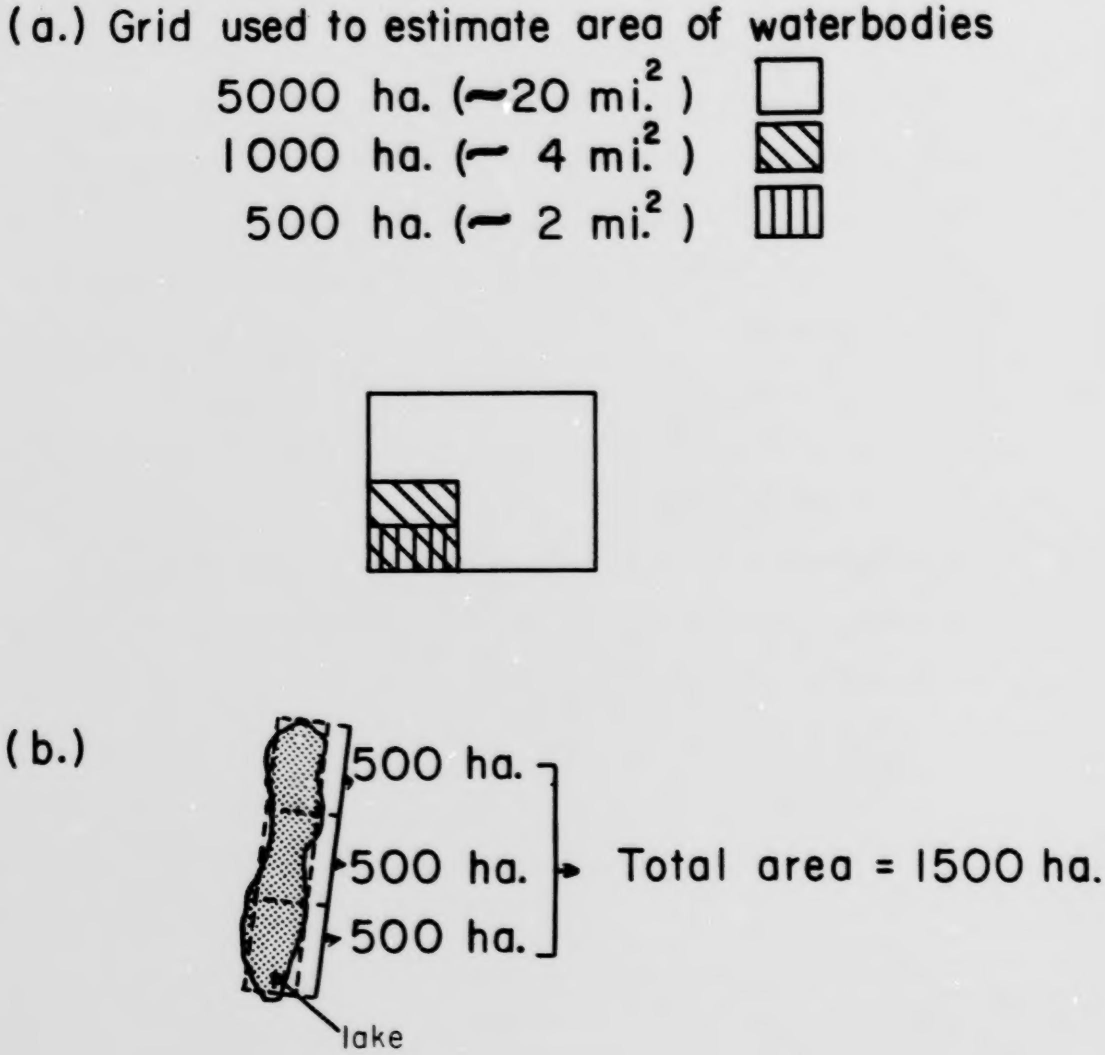

Fig. 1. (a) Grid areas, matched to scale of 1:250,000, that were used for determining water surface areas.

(b) Example of how grid areas were used to determine some lake surface areas.

Estimated potential fish yields were found using Ryder's (1965) morpho-edaphic index (MEI). This MEI is derived from the ratio of total dissolved solids (TDS) to mean depth. The relationship between MEI values and fish yields for a number of Ontario lakes fished intensively over a series of years showed a positive correlation which Ryder (1965) described by regression analysis. This regression equation could then be used to predict potential fish yields of other lakes, once the MEI for a lake had been determined. The regression equation used was:

$$Y = 1.381\ x^{0.446}$$

where Y = estimated potential fish yield in kg $ha^{-1}yr^{-1}$ and

x = the MEI value.

The species composition of fish yield in the present study was based on experimental fishing, as well as the yield partitioning approach used by Colby *et al*. (1982).

PART III

PAST AND CURRENT TRENDS IN FISH RESOURCES USES

A History of Fishing in Manitoba[1]

Fish resources of North America were being exploited long before European settlement. Archaeological evidence indicates freshwater fishes were an important food item to most tribes native to Canada. Aboriginal methods of capture included spears, fish traps and gillnets. These traps and nets were often fabricated from local materials such as the inner bark of willow or cedar roots.

During the early stages of European settlement in Canada, the importance of ready local food determined the pattern of settlement. Many trading post and wintering station sites of early Europeans were selected according to the abundance of nearby whitefish stocks. Furtraders and explorers seeking new transportation routes frequently depended upon fish for personal consumption and as food for dog sled teams. Fish were also important to a growing population of Metis, people of mixed European and Indian parentage. Much of the Indian way of life, including the use of fish as a staple food, was adopted by the Metis people. The Metis also used fish as a commercial or trade item.

[1] Information sources: Skaptason 1926, Anonymous 1966, MacPherson 1972, Pelletier 1977, Carruthers 1981.

Oral reports from Metis families indicated that their forefathers used fish to barter for tea, clothing and tools from Hudson's Bay Company posts (Pelletier 1977).

As the communities of European settlers grew and developed, some individuals soon specialized in fishing for sales to local markets. With increasing transportation networks, markets improved and fish sales expanded beyond local communities.

The first records of commercial fishing in Manitoba date back to 1872 when a few men from Winnipeg established a fishing station on the Little Saskatchewan River, now called the Dauphin River (Skaptason 1926). They set out to the Winnipeg market with fresh and salted whitefish (*Coregonus clupeaformis*). This venture soon failed due to poor transportation facilities and an abundant supply of fish in the Assiniboine and Red rivers within the confines of Winnipeg. The first successful commercial fishery began a decade later (1882) with a fishery operating from one sail boat on Lake Winnipeg. Increasing fishing effort in succeeding years boosted fish landings from 127,000 pounds in 1883 to 3.9 million pounds in 1893. Fish production increased with the introduction of more efficient freight and fishing boats and in response to expanding markets. By 1884, the first steam powered tugboat was in service on Lake Winnipeg. In the same year, export sales to the United States exceeded local sales. With the success of fishing on Lake Winnipeg, limited commercial fishing operations were begun on Lake Manitoba in 1885 and on Lake Winnipegosis by 1890. The early stages of fishing operations on these two lakes, however, were hampered by poor transportation facilities.

A key factor in the growth of Manitoba's commercial fishing industry has been the development of transportation systems. Fisheries on Lake Manitoba and Lake Winnipegosis expanded rapidly after the construction of the railroad to Winnipegosis in 1897. Development of commercial fishing in northern Manitoba has also been closely linked to railway and road expansions. A rail line to The Pas was completed in 1908. The extension of this line to the Port of Churchill was finished in 1929. As the railroad was extended into new areas, commercial fishing operations were begun wherever opportunities presented themselves. By 1925, some 20 large northern lakes were being fished. This number had increased to about 40 lakes by 1938.

Further advancements in commercial fishing resulted as mechanized equipment was introduced. Steam tugs made it easier and quicker to get sail boats to and from fishing grounds. Between 1920 - 1930, gasoline engines in fishing boats replaced sail power. With increased speed and dependability more fresh fish was shipped to markets. Greater amounts of fresh fish enabled Manitoba fishermen to compete more effectively in the marketplace. Several fisheries, such as Lake Manitoba and the northern lakes, were restricted to winter seasons only. Early forms of winter hauling had been by horses and sleighs. The advent of caterpillar-type tractors in the mid-1930's dramatically improve winter hauling. Each tractor could haul three times the cargo of a horse-drawn sleigh and could be operated around the clock. In many cases, distant northern fisheries became economically feasible because these tractor trains would carry supplies to remote communities and back haul fish at reduced rates.

Innovations and modifications to fishing gear have also helped in the development of Manitoba's fisheries. Although gillnets have remained the principal gear, they were improved in 1914 when cotton webbing replaced linen. The changeover from cotton to nylon webbing, which is stronger, more durable and more efficient, was begun in 1948. Pound nets had been used early in the Manitoba fishery, but were rapidly phased out. Beach seines and trap nets are still used in specialized fisheries such as carp or spring mullet (sucker) seasons. For winter fisheries, improvements came with the advent of the "jigger" near the turn of the century. Winter fishing efficiency was increased when snowmobiles, and later powered toboggans, replaced horse and dog teams. Axes were replaced by needle bars and ice chisels. These ice tools have, in turn, been supplanted by power ice augers in more recent years.

A growing fishing industry did initiate concerns about fish stock abundance as early as 1884. Regulations limiting the number of nets per boat, restricting commercial fishing on Sundays, and confining fishing to the north basin of Lake Winnipeg were enacted by 1892. The artificial rejuvenation of fish stocks had been attempted in the early 1890's. By 1894, the first fish hatchery in Manitoba was built at Selkirk. This location did not prove suitable and was closed in 1914 and replaced by another hatchery at Gull Harbor. A second fish hatchery was built at Berens River in 1907. This site also proved unsatisfactory and so the hatchery was moved to the mouth of the Dauphin River. The Dauphin River fish hatchery is the only former hatchery location still in use today. Hatchery buildings at this site have twice been destroyed by fire; once in 1924 and again in 1976. Fish hatcheries currently operating are the Whiteshell Hatchery near West Hawk Lake in the Whiteshell Provincial Park, the Grand Rapids Hatchery and Dauphin River Hatchery on northern Lake Winnipeg, and the Swan Creek Hatchery on the south basin of Lake Manitoba. The Duck Bay Hatchery on Lake Winnipegosis operated until 1982 when it was destroyed by fire. The first hatchery on Lake Winnipegosis was opened in 1909 on Snake Island, which is in the southern end of the lake. Plans have been proposed to rebuild the hatchery on Lake Winnipegosis.

Other major concerns confronting those who were involved in the early stages of Manitoba's commercial fishing industry were the building of dependable markets and the negotiation of acceptable prices for their products. The Manitoba fishing industry, especially during its early stages, has had to compete with the much larger Great Lakes fisheries. During the days of poor transportation, Lake Erie fishermen were in a much more favourable position to sell their fish to a nearby and expanding American market. Several of the largest U.S. cities were located on Lake Erie in the 1870's and much of the North American population was centered around Lake Erie when modern transportation was developing. Continuing poor fish prices and an ever-increasing control exercised on the Manitoba fishery by American fish marketing interests led to the formation of the Manitoba Cooperative Fisheries Ltd. in 1928. It was hoped this cooperative would give Manitoba fishermen more advantages in the market-place and, ultimately, greater control over their own destiny. However, internal organizational problems caused the cooperative to fail. After it was abandoned, several independant fish companies then controlled Manitoba's fish marketing. Problems with inadequate fish prices to fishermen still persisted. Over the next few decades government and industry committees and commissions reviewed Mantioba's fisheries problems. One such group was the McIvor Commission which led to the formation of a federal Crown agency, the Freshwater Fish Marketing Corporation (FFMC), in 1969.

The major objective of FFMC was to stabilize freshwater fish marketing and maximize returns to the primary producer, the fishermen. This goal was accomplished by organizing a marketing strategy among different freshwater fishery groups in Canada. At present, FFMC represents fisheries from Northwestern Ontario, Northwest Territories and the three Prairie Provinces (Fig. 2). Manitoba fisheries contribute about 60 per cent of the fish handled by FFMC. This amount constitutes approximately 25 per cent of Canada's total freshwater fish production (Fig. 3).

Lake Winnipeg, Lake Winnipegosis and Lake Manitoba have been the three most important single fisheries in the Province. About 60

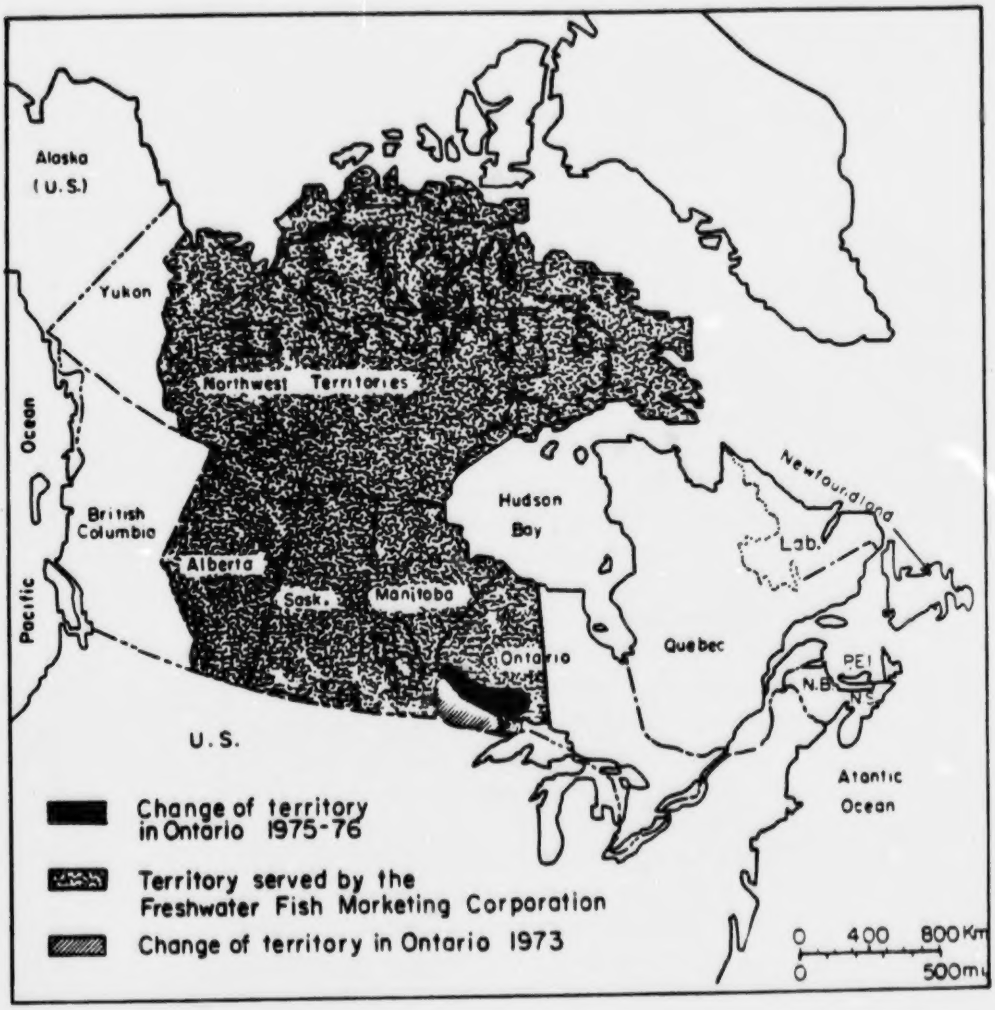

Fig. 2. The area served by the Freshwater Fish Marketing Corporation (Taken from the F.F.M.C. Annual Report, 1980).

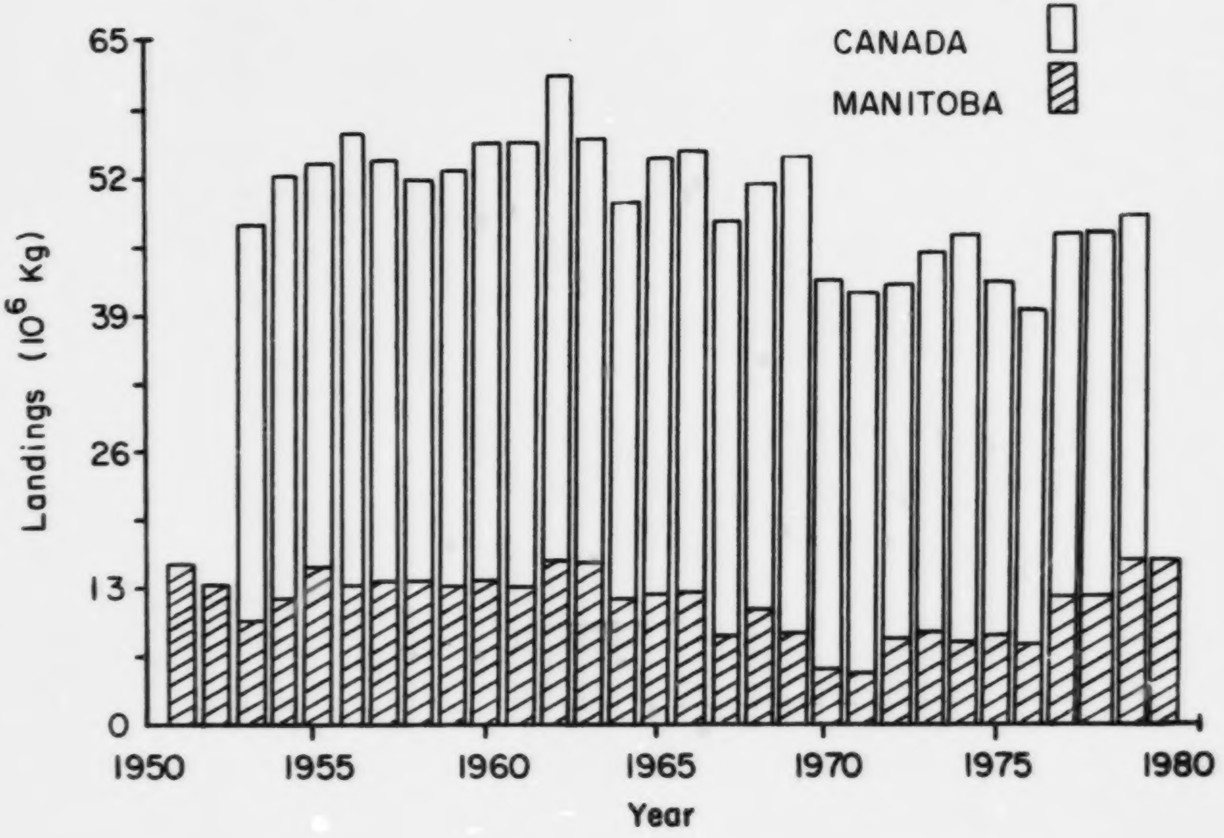

Fig. 3. Manitoba's annual freshwater fish production in relation to Canada's total annual freshwater fish production, 1950 - 1980. Data from source documents no. 2 and 3.

per cent of Manitoba's commercial fish production comes from these three waterbodies alone. Whitefish was the most important species caught from these lakes until their abundance declined in the 1920's and 1930's. Dwindling whitefish catches were offset by increased production of other fish species. These were mainly walleye (*Stizostedion vitreum*) from Lake Winnipegosis and walleye and sauger (*S. canadense*) from Lake Manitoba and Lake Winnipeg. Whitefish are still caught in significant quantities from Lake Winnipeg and the northern lakes, but the value per unit weight is less than that of walleye or sauger.

Besides commercial fishing, sport fishing is becoming increasingly important to the Manitoba economy. Sport fishing forms a significant part of recreational and tourism activities in Manitoba. Angling licence sales have generally increased annually and more than 100 tourist lodges in Manitoba rely solely or extensively on sport fishing for income. Angling is the principal sport fishing method, but spearfishing, bowfishing and dipnetting are also popular. At present, bowfishing is restricted to coarse fish species such as mullets (*Catostomus* spp.) and carp (*Cyprinus carpio*). Dipnetting is only allowed for mullets in spring. Historical information on Manitoba's sport fishery is lacking, but recent surveys indicate that game fish production has increased from 3.6 million kg in 1975 to 4.0 million kg in 1980.

A growing interest in sport fishing has generated both positive and negative benefits. On the positive side, larger revenues have been generated in direct and indirect ways. Increased sales of sport fishing licences and angling equipment provide some of the direct benefits, while indirect proceeds come from lodging, travel expenses, subsistence, etc. The negative side of growth has been increased fishing pressures which place extra burdens or stress upon available fish stocks. With the increased growth in sport fishing, conflicts have emerged among recreational and commercial users. Greater amounts of information on the sport fishery are needed so that fishery managers can adequately assess the biological implications from an expanding sport fishery.

Aquaculture or fish farming is a relatively recent phenomenon in Manitoba. It was introduced in the late 1960's, when rainbow trout fingerlings were planted into small, shallow, prairie pothole lakes, allowed to grow for the summer and then harvested in the late fall or early winter before winterkill conditions materialized. Trout farming became popular in the early 1970's. In 1971, for example, there were 182 permittees and 63 licencees; permits allowed individuals to raise trout for their own consumption while licences were required to sell trout on a commercial scale. Commercial trout farming has not been as successful as first believed. By 1979, the number of licenced trout farmers dropped to 18. Interest in trout farming for personal use has, however, remained high. In 1981/1982, 372 trout farming permits were issued as opposed to 30 commercial trout licences.

Small fish such as minnows (_f. Cyprinidae_) have been long utilized as bait by sport fishermen. A commercial bait fishing industry has existed in Manitoba since at least 1950. In 1970, a new plan was instituted for the control of commercial bait fishing. This plan consisted of dividing the province into 2,279 equal-sized bait fish blocks. Commercial operators were then licenced to fish one or more blocks. In 1971/72, 21 bait fishermen were licenced. Presently (1981/82) there are 33 bait fishermen who fish a total of 257 blocks. A limited number of men is also licenced for the production of some live bait fish.

Past Trends in the Commercial Fishery

In the following discussion of the commercial fishing industry in Manitoba, the fishery is divided into several statistical regions. These regions are northern Manitoba, southern Manitoba and the three major lakes (lakes Winnipeg, Winnipegosis and Manitoba). This regional breakdown is possible because of the manner in which the commercial fish production statistics have been compiled. Statistics for other fish resource uses in Manitoba could not be as readily catalogued according to region and were therefore considered primarily on a province-wide basis.

The first recorded attempts at commercial fishing in Manitoba, as previously mentioned, dates back to 1872. From this beginning, commercial fishing in Manitoba grew to become the second largest freshwater fishery in Canada, outranked only by the Great Lakes fisheries in Ontario (Regier 1976). The growth of commercial fishing in Manitoba has been, and largely still is, integrally linked with settlement and the development and growth of transportation facilities. The construction of a railroad to Hudson Bay and growth of other modes of transportation (eg. tractor train, powerboat and airplane) were important in opening up commercial fisheries on Lake Winnipegosis and on lakes north of the 53rd parallel.

As early as the 1920's, the bulk (approximately 90%) of Manitoba's commercial fish production was exported (Skaptason 1926). Most exported fish went to markets in the eastern and north-central U.S. Except for the development of some overseas markets, the present-day fish production from Manitoba waters is still largely sold on U.S. markets.

Before examining the regional commercial fisheries of Manitoba, it is worthwhile to briefly examine the fisheries on a province-wide basis. Figure 4 illustrates annual commercial landings of fish from all Manitoba waters between 1914-1950. Reasons for the wide fluctuations in total catches during the early years of this period are speculative. The early peak between 1914-1918 and subsequent slump in 1919-1920 may have been due to an increased demand for food production during World War I, followed by a decreased demand at war's end. A sharp increase in production in the late 1920's could have been a reflection of increased markets in the U.S., since over 90 per cent of Manitoba's exported fish went to the U.S. at that time. Coincidental to the start of the 1930's Depression, Manitoba's fish production began another downslide to under 8 million kg in 1931. Commercial fish production exhibited a fairly steady increase during the remainder of the 1930 decade. This increase was perhaps related to the unavailability of jobs in other industries and the necessity for alternate food sources during the drought which accompanied the Depression years.

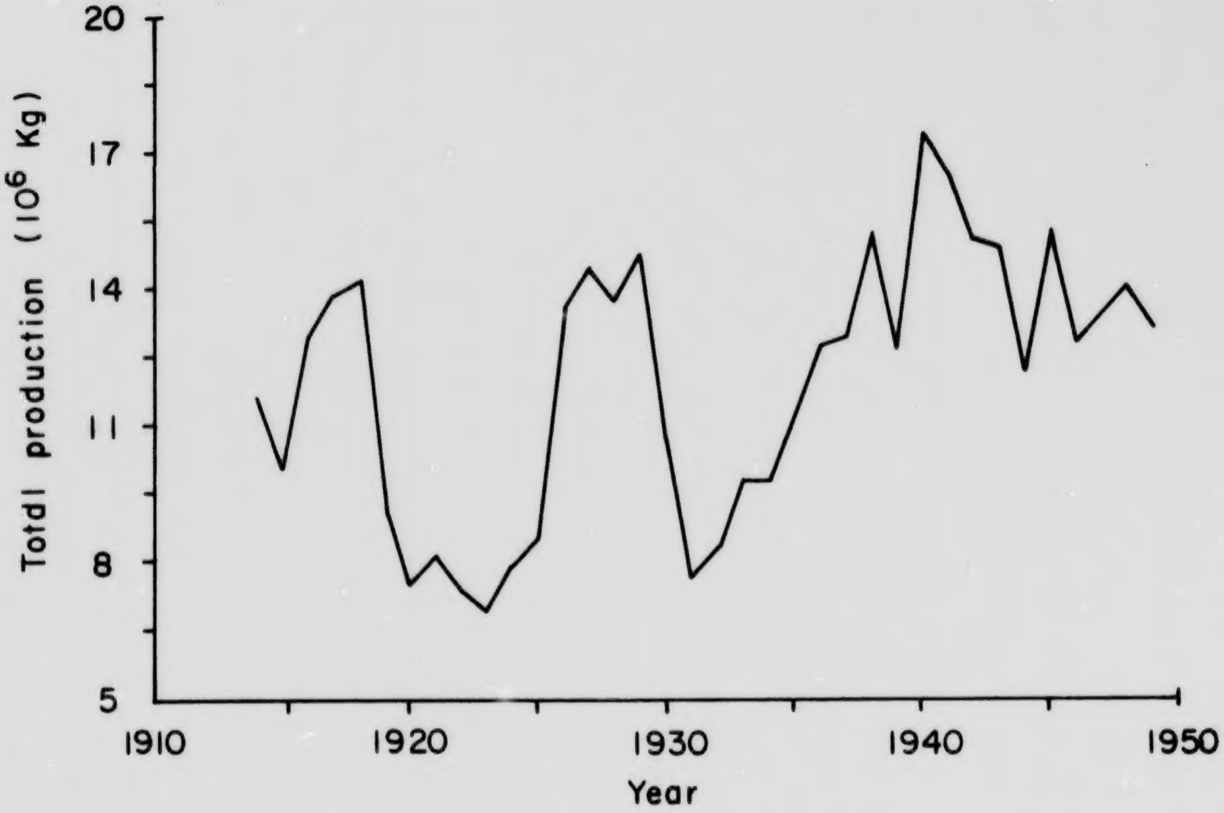

Fig. 4. Total commercial landings (marketed weight) of fish from all Manitoba waters for the period, 1914 - 1950.

The largest annual catch ever experienced in Manitoba's fishing industry was taken during the second year of World War II, when the production was 17.6 million kg (38.9 million pounds). Except for 1939 and 1944, annual catches during the war exceeded 15 million kg. The demands for food commodities during the war were undoubtedly responsible for these large catches.

Following World War II and up to 1966, the level of commercial catches from Manitoba waters has remained relatively stable around an average of about 14 million kg. In the period 1950-1980, landings in all years from 1950 to 1966, except one, were above the average annual catch (12.6 million kg) for the 31 - year period (Fig. 5). In the one exception, 1953, total landings dropped below 11 million kg. This drop could have been the result of restrictions placed on whitefish exports to the U.S. due to Triaenophorus spp. infestations. Because of these restrictions, whitefish production from a number of northern lakes had to be discontinued. Commercial production again peaked in 1962 and 1963, when approximately 16.2 million kg were landed each year. This peak was in large part related to strong year classes and good catches of walleyes from some northern Manitoba waters (Derksen 1967, Annual Reports 1962, 1963) as well as strong demands for freshwater fish, particularly walleye and sauger, in U.S. markets (Annual Reports 1961, 1962, 1963 and 1964). Also about this time walleye stocks in the Great Lakes, and especially Lake Erie, were in a serious state of decline.

Commercial catches progressively declined following 1963, and dropped to record lows in 1970 and 1971. A series of events, both

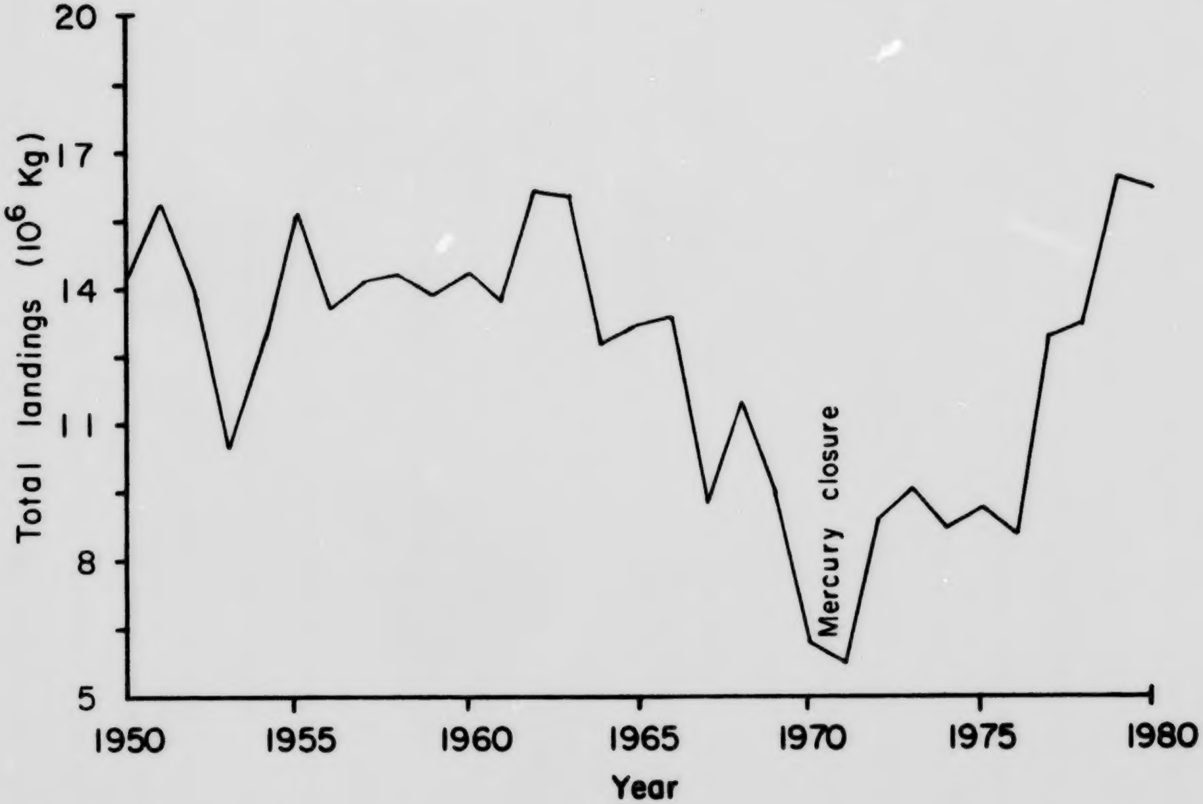

Fig. 5. Total commercial landings (marketed weight) of fish from all Manitoba waters for the period, 1950 - 1980.

natural and man-made, were responsible for this decline in production. As will be seen later, both the Lake Winnipeg and Lake Winniepgosis fisheries were in a general state of decline during this period. Whitefish stocks in northern Lake Winnipeg and walleye stocks in the south end and Channel areas of Lake Winnipeg and in Lake Winnipegosis were being subjected to heavy fishing pressure. Poor catches were realized from Lake Manitoba in 1964 because of extremely unfavourable winter fishing conditions (Annual Report 1965). The poor availability in fish at this time resulted in a sharp increase in prices. With the continued strong demand for fish, prices reached record levels in 1965 (Annual Report 1966). These high prices, particularly for walleye and sauger, resulted in consumer resistance and a deterioration in U.S. export markets. The inventory of fish in cold storage began to mount in 1966 (Annual Report 1967). These conditions carried through into 1967. Approximately 1 million kg of walleye and sauger were being held in cold storage. Many fishermen were voluntarily dropping out of the fishery. Under these circumstances, the Manitoba production dropped to 3.8 million kg in 1967. It has also been suggested that impending formation of a freshwater fish marketing board may have contributed to the poor catches in 1967 (Annual Report 1968). In the following year, production increased abruptly. This upturn in production was due to lower fish prices and improved market demands in the U.S. Commercial catches then dropped consistently from 1969 to 1971. A number of factors may have been involved with and responsible for this general decline. Firstly, overexploitation of some stocks was a problem on the Lake Winnipeg and Winnipegosis fisheries.

Secondly, with the inception of the Freshwater Fish Marketing Corporation in 1969, production may have dropped due to the lack of lakeside management facilities. This situation may have been particularly applicable in the case of the northern fisheries. Finally, the discovery of mercury contamination in fishes from the Saskatchewan River in 1969 had a drastic effect on fish catches. The low catches during 1970 and 1971 were the result of commercial fishing closures on Lake Winnipeg and the Saskatchewan River because of mercury pollution. These closures allowed some respite for overfished stocks in Lake Winnipeg and the institution of more stringent control over the fishery. Since the Lake Winnipeg fishery re-opened in 1972, a fishing-up period has occurred and boosted the total provincial catch to the 1950-1960 level. Commercial fish production from Manitoba waters in 1980 increased to over 16 million kg. Excluding the years 1970 and 1971, when production was overly depressed because of the mercury problem, annual catches during the 14-year period (1967-1980) have generally been about 10 per cent below the average annual landing (12.6 million kg) for the period 1950-1980. The reasons for this lower level of production are not evident at this time.

The commercial production of fish from Manitoba between 1950-1976 has been closely related to the number of men (licenced fishermen and hired men) engaged in the fishery (Fig. 6). This trend suggests production levels influenced the number of participants in the fishery. Prior to 1972, there were no restrictions on entries to most major commercial fisheries. Consequently, if catches appeared especially good in one year, more men would enter the fishery in

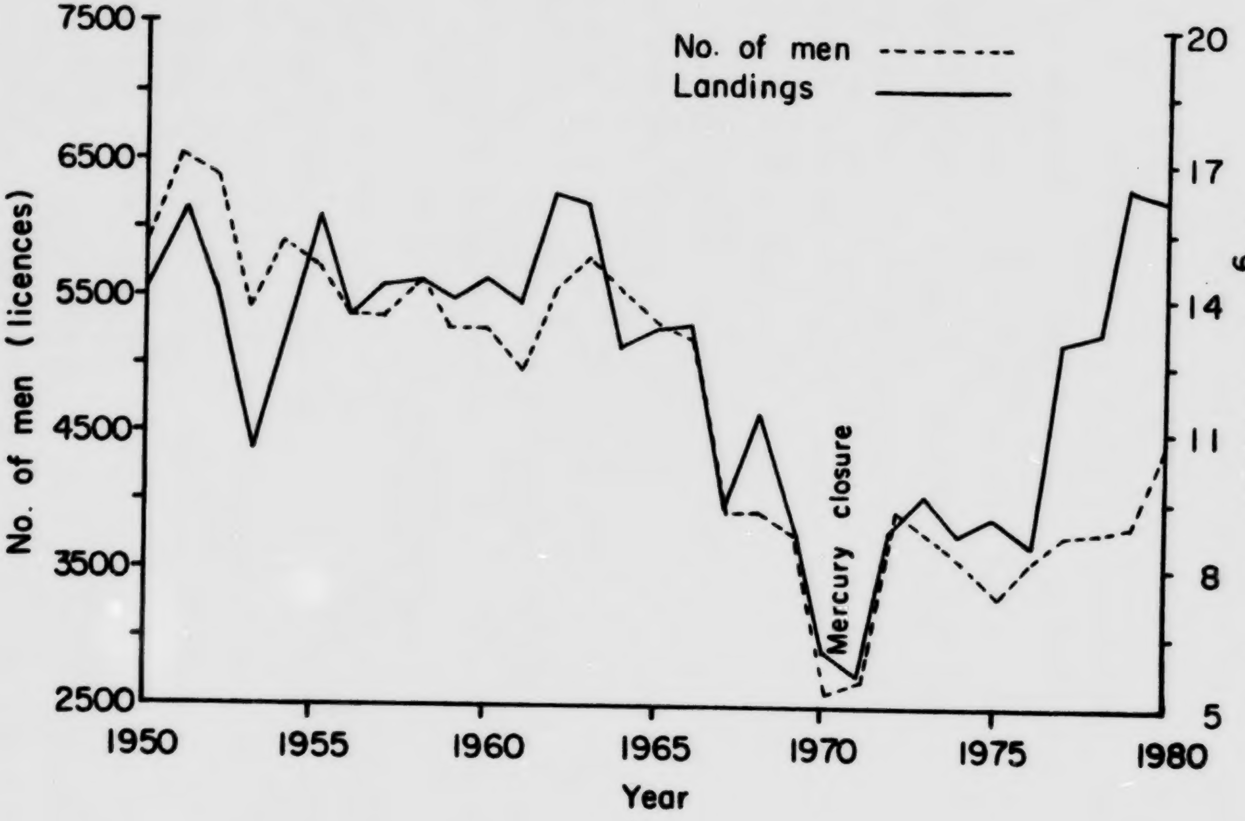

Fig. 6. Number of commercial fishing licences issued and total commercial landings (marketed weight) of fish from all Manitoba waters for the period,1950 - 1980.

following years. To a certain extent then, the magnitude of catches is related to the number of men in the fishery, in that the degree of participation reflects fishing effort. This relationship may be misleading, however, since all men licenced to fish in a given year did not necessarily fish or expend full effort. The relationship between men and production also is not consistent. Commercial catches in the late 1970's increased significantly despite very moderate increases in the number of fishermen (Fig. 6). This discrepancy is attributable primarily to significant increases in catch quotas on Lake Winnipeg after 1975.

It should be noted that the number of fishermen in the commercial fishery each year, as presented in Fig. 6, is higher than the actual numbers of individuals (licenced fishermen and hired helpers) who were employed in the fishery. The statistics are based on numbers of licences sold, and therefore are inflated by double counting individuals fishing more than one season or one area. Kowal (1976) eliminated the double counts of commercial fishing licences issued in the 1975/76 season and determined that there were actually 2700 individuals employed as fishermen and helpers in Manitoba, instead of 3365 men as shown in Fig. 6. This represented 20 per cent fewer individuals than licences issued. Since 1976, Annual Reports have presented statistics which eliminate the double counts. During the years, 1976-1980, there were about 17 per cent fewer individuals than licences in the Manitoba fishery.

Ignoring the years 1970 and 1971, the number of men fishing in Manitoba has declined from a high of 6578 in 1951 to a low of

3364 in 1975 (Fig. 6). The mercury closure on Lake Winnipeg was in effect during 1970 and part of 1971 and was responsible for the sharp decline in number of men at that time. There has, however, been a general decline in the number of men engaged in Manitoba's commercial fisheries over the 1950-1980 period. The decline, particularly in the fisheries on the three major lakes, between 1950 and 1970 may be partially attributed to natural attrition and limited ingress from the younger age groups (England and Peters 1971). Furthermore, the abrupt decline in production and number of men in the middle to late 1960's was related to poor prices, high freezer inventories of fish and depressed markets. The low economic returns produced little incentive for individuals to fish. The provincial government of the day had also introduced a manpower retraining program. This program's objective was to introduce fishermen to other occupations and reduce the workforce directly employed in fishing.

After the mercury closure on Lake Winnipeg in 1970 and 1971, commercial fish production began increasing, but without any close association to the number of men engaged in the fishery. This circumstance appears to be related to several factors. First, after 1972 fisheries management introduced controls on the number of fishermen allowed on some lakes. Secondly, there were, as previously stated, significant increases in catch quotas on some of the major fisheries. Finally, there may have been a deliberate decision on the part of some fishermen to discontinue fishing. Some fishermen may have dropped out of the fishery between 1972 and 1975. After 1973, the dramatic rise in world oil prices increased fuel and transportation costs. The impact of these events were particularly noticeable in fisheries on remote northern lakes; the added costs severely reduced profit margins.

The lack of any proportional association between total production and numbers of active participants in the commercial fishery will probably continue in the future. Management policies will undoubtedly influence the level of participation. More emphasis is now placed on stronger controls or management measures to ensure an efficient and continuing viable fishery. Future considerations will be aimed at making the commercial fishery more self-supporting with less reliance on government subsidization. This basically requires fewer fishermen producing all the catch, particularly if equipment and operating costs continue to escalate more rapidly than the returns to the fishermen. The present policy of limiting entry to the fishery already widened the gap between production and participation.

Comparisons between the regional commercial fisheries for the period 1950-1980 shows Lake Winnipeg as the single most important fishery in Manitoba (Fig. 7). Except during the 1960 decade, the Lake Winnipeg fishery has out-produced all other regional fisheries. The commercial fishery in northern Manitoba, in terms of production, is presently second in importance, but during the 1960's it produced more than Lake Winnipeg. Production levels from Lake Winnipegosis and Lake Manitoba fisheries are fairly similar. Although production from Lake Winnipegosis has been about 0.5 million kg higher than from Lake Manitoba over the 1970-1980 period, the fish produced from the former, as will be discussed later, are of lower market value. Commercial

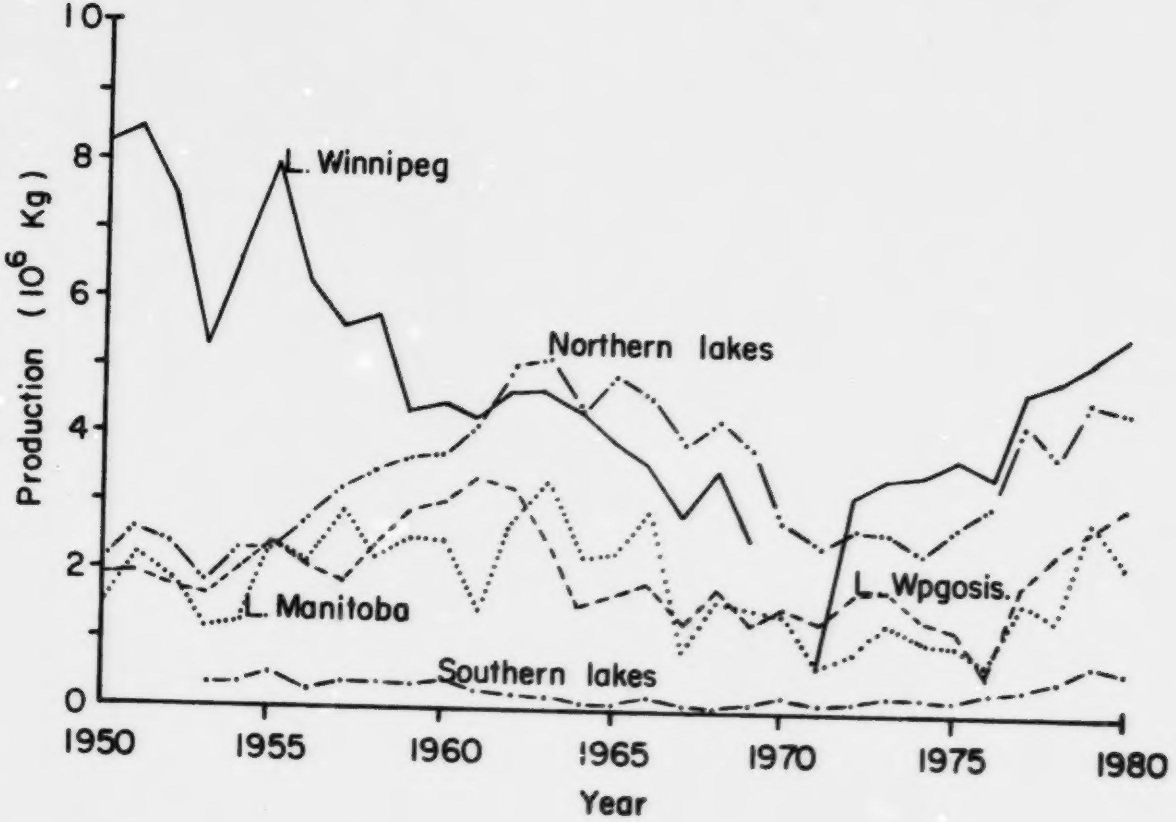

Fig. 7. Annual commercial landings of fish (marketed weight) from northern and southern lakes and the three major lakes in Manitoba, 1950 - 1980. Data from source document no. 3.

catches from southern Manitoba fisheries are of minor value in terms of quantities landed. Southern fisheries have usually produced less than 0.5 million kg yr^{-1}. The 1976-1980 production from southern lakes is slightly different than described in the Annual Reports. This is because some lakes listed as southern or other lakes in the Annual Reports are defined as northern lakes within this report.

The characteristics of commercial fisheries in Manitoba, i.e. the kinds of species exploited, vary depending upon the region in which the fisheries occur. Fisheries on the northern lakes and Lake Winnipeg are based primarily on high market-value species such as whitefish, walleye and sauger (Fig. 8). Commercial fisheries on southern lakes and Lake Winnipegosis, on the other hand, exploit a greater percentage of medium and low-valued species such as northern pike (*Esox lucius*) and suckers. The Lake Manitoba fishery produces a species mix which appears to be intermediate to the above two extremes.

Commercial Fisheries in Northern Manitoba

The commercial fishery in northern Manitoba dates back to the early 1900's, when it was centered on lakes situated primarily around The Pas. This is not surprising, since The Pas was one of the first major settlements north of the 53rd parallel and was linked to the south by railway at an early stage (1908). In the 1920's, approximately 20 northern lakes were being commercially fished (Skaptason 1926). There are presently more than 300 commercially

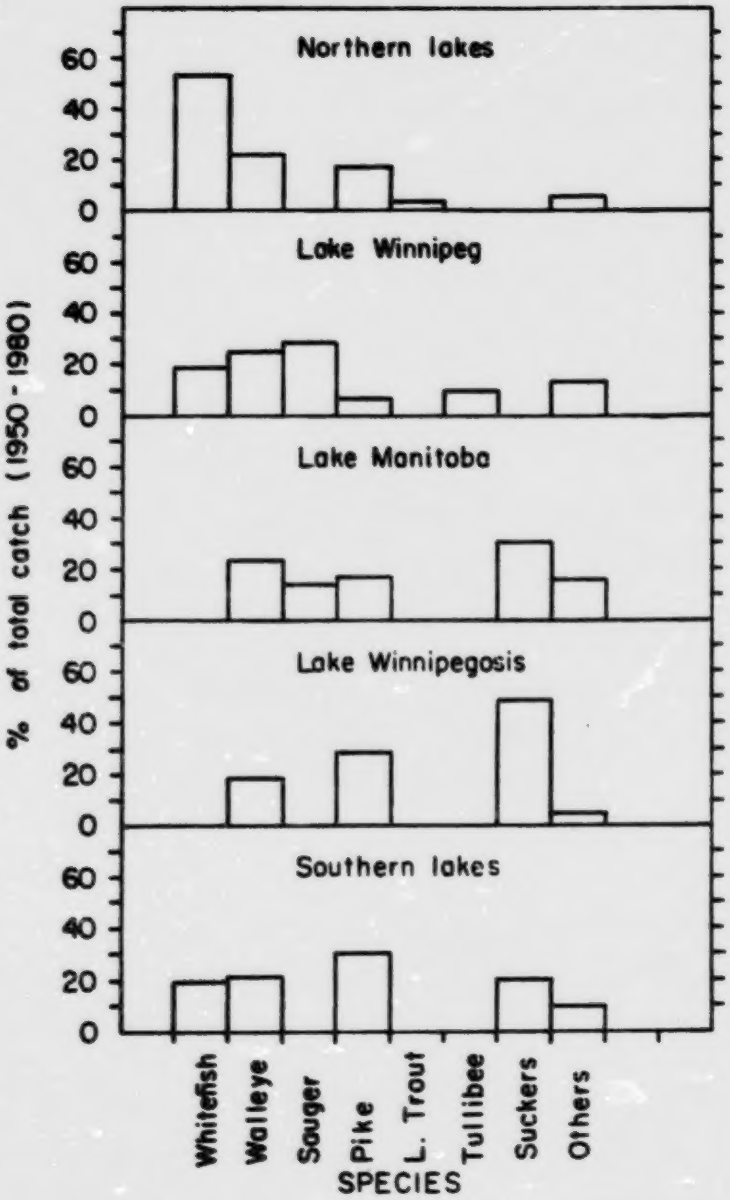

Fig. 8. Species composition of commercial catches by fisheries in various regions of Manitoba. Percent composition by each species in each area is based on the total contribution of each species to the total catch of all species from a region for the period,1950 - 1980.

fished lakes in northern Manitoba (Adams et al. 1976). All of these lakes, however, are not fished in each year. Statistics on the annual number of exploited lakes indicates that growth in the northern commercial fishery was gradual between 1936 and 1955 (Fig. 9). During this period, the fisheries were primarily active in the winter season. Fisheries at this time were probably more profitable during the winter season because of transportation factors. Since air transportation had not been fully developed, many of the goods and materiel going into remote northern communities were transported by tractor trains which could only operate in winter. These tractor trains, which otherwise would return empty, provided lower freight rates for the back haul of fish to rail or road terminals. Problems of maintaining fish quality during shipment over long distances were also avoided by winter fisheries.

After 1955, there was a sharp increase in the number of lakes exploited and the winter fishery gradually gave way to a summer fishery. The increased growth of the northern fishery was probably related to increased and improved transportation facilities in the north. The float-equipped bush plane, which could carry appreciable loads, was undoubtedly a significant factor in the development of summer fisheries (Stowe 1982). Since fresh fish command better prices than frozen fish, the summer fisheries had a price advantage over winter fisheries. It should be noted, however, that a decline in production from the Lake Winnipeg fishery was beginning to appear in the late 1950's (Fig. 7). Private fish companies then involved in the industry may have shifted their operations northward in order to increase production to meet market demands and compensate for production declines on Lake Winnipeg.

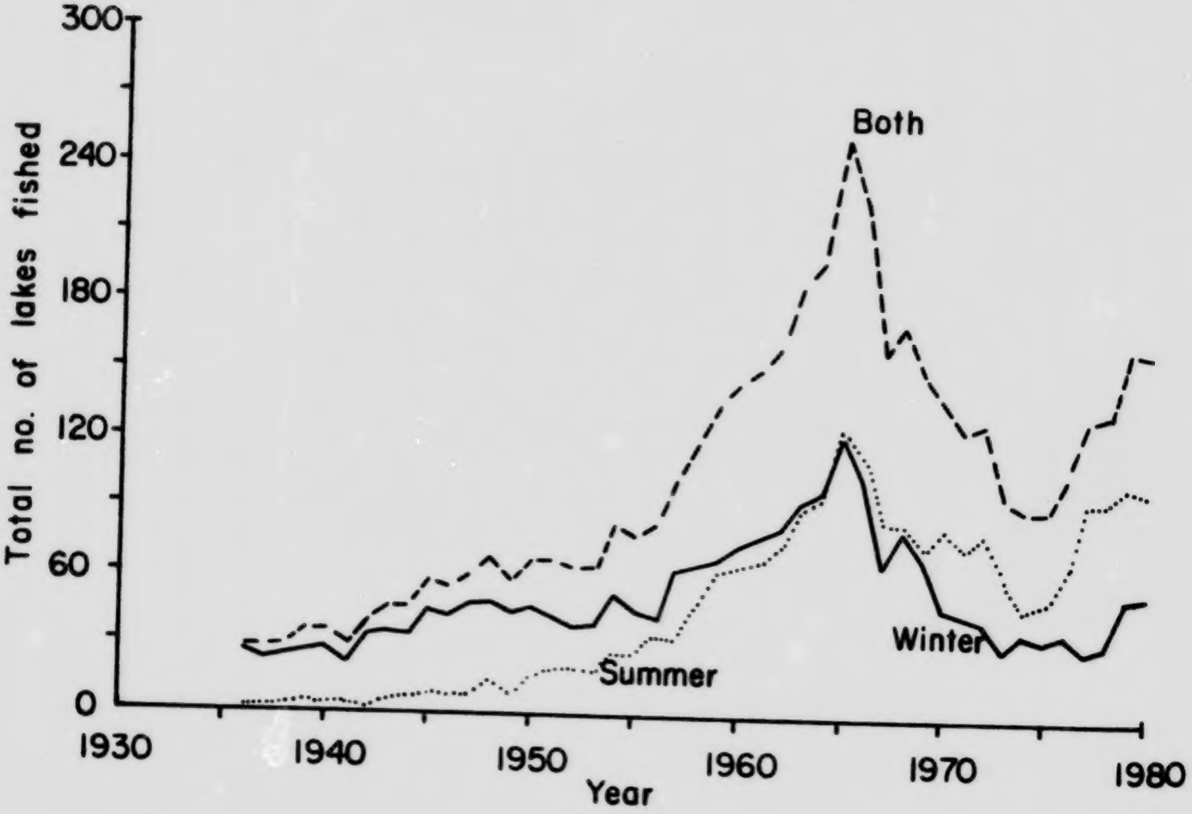

Fig. 9. The number of lakes in northern Manitoba commercially fished between 1936 and 1980. Data from source document no. 7.

The northern fishery peaked in 1965 (Fig. 9). This peak was undoubtedly attributable to strong market demands and high prices for fish during the early 1960's. Record or near-record catches of walleyes were made in 1963 and these fish initially commanded good market prices. As previously mentioned, intense fishing during the early 1960's, coupled with over-pricing of fish, resulted in a glut of fish on the market. Consequently, declines in demand and fishing activity occurred in the late 1960's. The decline in the northern commercial fishery following 1969 has, in part, been related to the introduction of the Freshwater Fish Marketing Corporation (Adams et al. 1976). Total withdrawal of private company agents from the fishing industry following the inception of the FFMC left a void, particularly in northern Manitoba, in the lakeside management of commercial fisheries.

The rapid growth in the northern fishery was almost entirely restricted to the summer fishing season. The number of commercial fishermen (i.e licences) engaged in the summer fishery surpassed the number of winter fishermen in 1957 and peaked at over 1200 men between 1963 and 1965 (Fig. 10). In contrast, the number of winter fishermen remained relatively constant between 500 and 700 over the period 1950-1966. The number of fishermen involved in the northern fishery during both seasons declined between 1967 and 1975, but involvement in the summer fishery has continued to be most important.

Growth in the northern fishery resulted in a significant increase in whitefish production. Annual production of whitefish increased from 1.2 million kg in 1950 to a record high of 2.9 million kg in 1963, a 142 per cent increase (Fig. 11). Walleye production

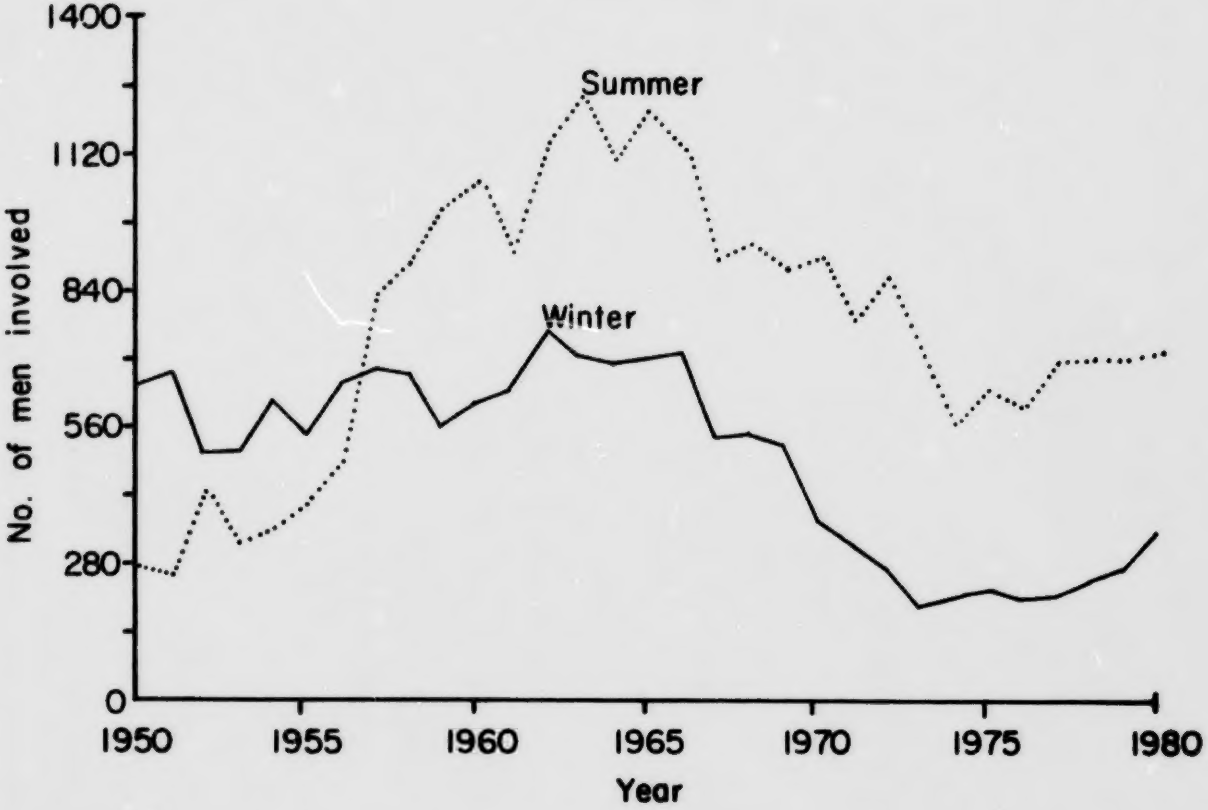

Fig. 10. The number of summer and winter fishermen (licences) in the commercial fishery in northern Manitoba, 1950 - 1980.

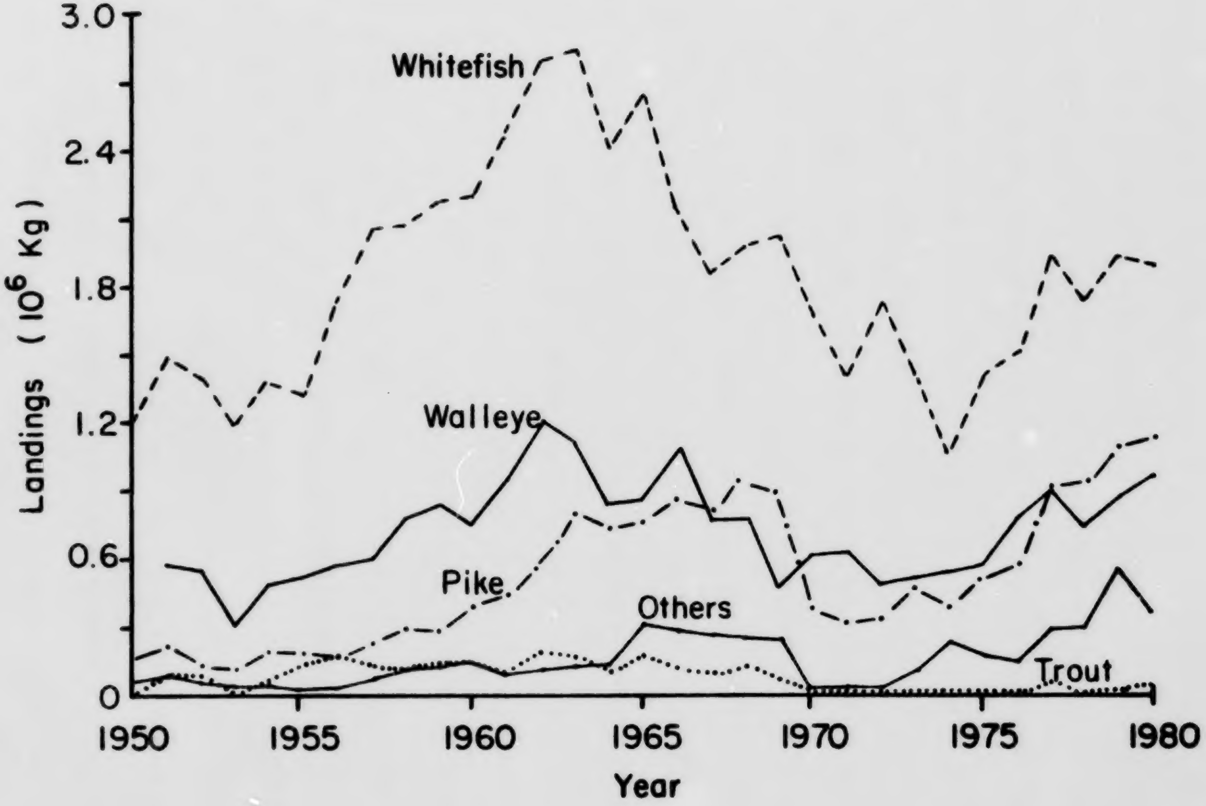

Fig. 11. Annual commercial catches in kilograms of walleye, whitefish, northern pike and lake trout from northern Manitoba lakes, 1950 - 1980.

during approximately the same period increased 261 per cent (0.36 million kg in 1953 to 1.3 million kg in 1962). Similarly, a steady increase was observed in northern pike production and, to a lesser extent, in lake trout (Salvelinus namaycush). Except for pike, production of the prime species by the northern fishery began to decline after the mid 1960's. Pike production peaked at 1.0 million kg in 1968 and then declined to levels between 0.23 and 0.45 million kg in the early 1970's. This low production is in part attributable to excessive mercury contamination of pike from some northern lakes and the new regulation, introduced in 1970, respecting mercury levels in commercial fish. There has also been a significant drop in lake trout production. The 1975 lake trout catch from northern lakes was only 7,300 kg; between 1950-1970 the annual catch varied from 45,000 to 227,000 kg. The decline may to some extent be related to overfishing and natural environmental conditions. Many northern Manitoba lakes are not deep enough to sustain lake trout populations. Those lakes having suitable habitat are usually marginal lake trout lakes and generally contain relatively small populations. Because of the small population size, restricted habitat, as well as the slow growth and maturation of the species, lake trout in most northern Manitoba waters are extremely vulnerable to overexploitation. In some lakes, for example Cedar and Moose lakes on the Saskatchewan River, lake trout populations were extirpated soon after exploitation began. Management regulations have also been imposed on some commercially fished lakes to protect and preserve lake trout stocks for recreational fishing.

The species composition of annual commercial catches by the northern fisheries has been comparatively stable over the last 25 years despite the fluctuations in catch volume. Except for several years, the contribution of whitefish to the annual catches has been over 50 per cent, but usually not more than 60 per cent (Fig. 12). Walleye production has contributed approximately 22 per cent of the annual landings. The percentage contribution of pike to annual catches has shown a gradual increase from 1950 to 1969. This increase possibly reflects improved prices for pike. As mentioned previously, the importance of lake trout in the northern fisheries has diminished. Other fish species, (eg. tullibee, yellow perch, sauger, lake sturgeon, goldeye, suckers, etc.) have contributed a minor portion of the annual catches; in most years during the 1950-1980 period, these other species have contributed less than 5 per cent of the catch. Production of coarse fish (suckers, burbot, tullibee, etc.) from northern lakes has been low because of the low price paid to fishermen for them and the high cost of transporting them south. Also, fishermen are not given transportation subsidies for coarse fish. Catches of coarse fish from northern lakes are frequently discarded and do not appear in the production records.

Based upon trends which have occurred over the past decade, it would appear that the commercial fishery in northern Manitoba, if left to its own devices, will eventually collapse or be greatly diminished. This situation is not due to any lack of a harvestable surplus. The major problem in the northern fishery, although other problems exist, is transportation and the related high costs of

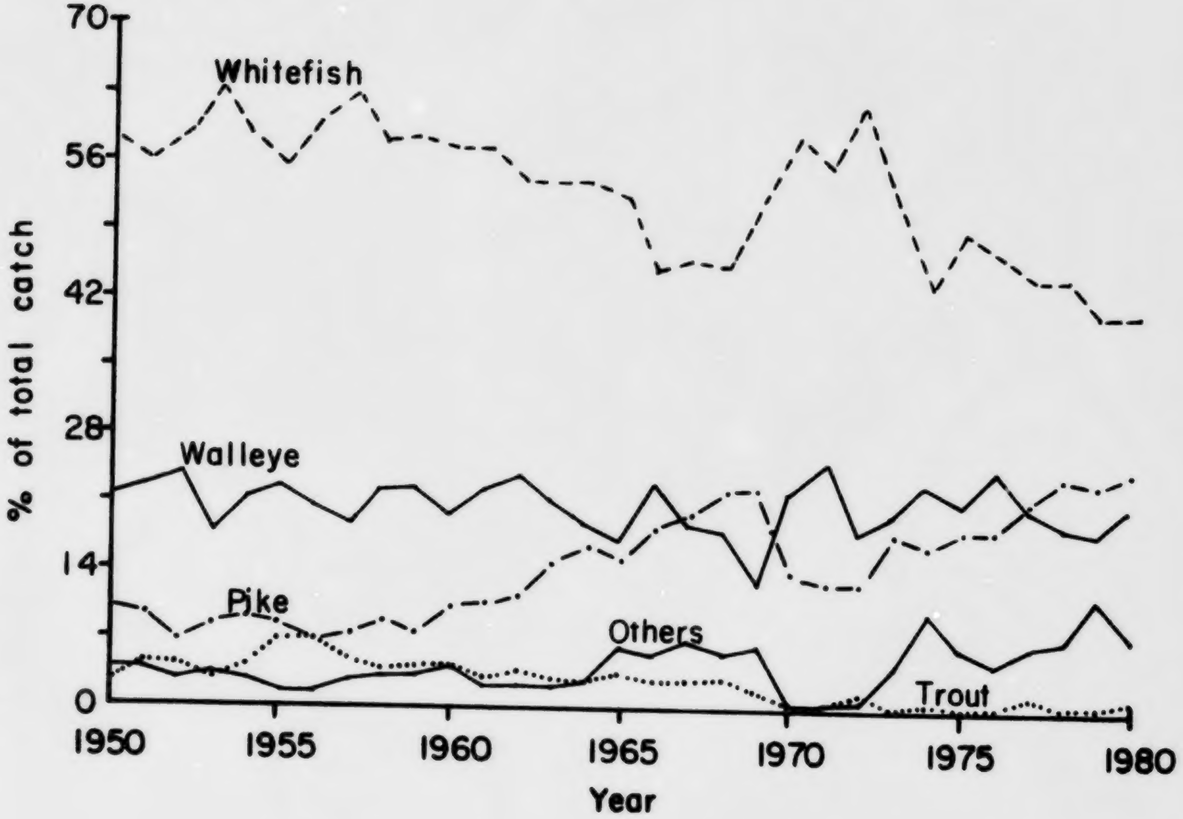

Fig. 12. Species composition of annual commercial catches from northern Manitoba fisheries, 1950 - 1980.

production (Adams et al. 1976). Present day transport of commercial fish from northern lakes to local delivery points depends heavily on aircraft. Of the 300 or so commercially fished lakes in northern Manitoba, transportation of fish from one-third depends to some degree on aircraft (J. Allen, unpublished data). The high cost of fuel has seriously eroded profit margins in these cases.

In addition to the transportation problem, the northern Manitoba fishery is beset with several other problems. Two of these problems relate to the Triaenophorus infestation of whitefish and tullibee and mercury contamination in pike, walleye and lake trout. Since roughly half the production from many northern lakes is whitefish, the degree of Triaenophorus infestation may be an important determinant of the economic viability of commercial fisheries on individual lakes. There are three classifications of whitefish with respect to Triaenophorus infestation; these are export (A), continental, (B) and cutter (C) grades[1]. Export grade whitefish are lightly or non-infested and command premium prices in the U.S. "smoker" market. Continental grade whitefish are moderately infested and are lower in price. Lowest prices are paid for cutter whitefish which are heavily infested. Cutter whitefish are shipped to FFMC in the headless-dressed form and must be filleted before they can be marketed. Most lakes in northern Manitoba, according to Wickstrom and Merner (1970), contain either B or C grade whitefish. However, most of the whitefish production from northern Manitoba lakes is export (A) quality (G. Prouse, pers. comm.). This indicates that exploitation of medium and low quality whitefish from northern lakes is not an economically viable proposition because of the lower fish prices and high transportation costs. Furthermore, the transportation of cutter whitefish from the north is not supported by government subsidies. It should also be noted that the transportation/infestation problem is most acute in the far northern lakes; only 16.5 per cent of far northern lakes were A lakes compared to 30.4 per cent A lakes in the north-central region (Table 1).

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[1] A = <40 cysts per 45 kg.

B = 41-80 cysts per 45 kg.

C = >80 cysts per 45 kg.

Another problem affecting the northern fishery is the presence of mercury contamination of fish, primarily pike, walleye and lake trout, in a number of lakes. In most cases, the contamination is believed to originate from natural sources (Derksen 1978). In some lakes, a portion of the pike, walleye and lake trout populations may contain residue levels exceeding the federal health standard for mercury in commercially sold fish. This standard is 0.5 parts per million (ppm). Mercury data compiled by the federal Department of Fisheries and Oceans (Fisheries Inspection Service) indicates that each shipment of pike, walleye and lake trout from approximately 40 waters in northern Manitoba must be detained for mercury inspection. Fish from a given lake are detained when more than one sample in eight drawn from a shipment contain in excess of 0.5 ppm mercury. When fish are detained, FFMC imposes a charge to the fishermen of two cents per pound to defray costs for the extra storage and handling required. In addition to the waters from which fish are detained, there are also

Table 1. Number of lakes in northern Manitoba which contain whitefish of various levels of Triaenophorus infestation. (Percentages are given in parentheses. Data extracted from source document no. 59.

Region	Level of Triaenophorus Infestation (No. of lakes)		
	A	B	C
North-central	96 (30.4)	132 (41.8)	88 (27.8)
Northern	20 (16.5)	78 (64.5)	23 (19.0)
Total	116 (26.5)	210 (48.1)	111 (25.4)

Table 2. Waters in northern Manitoba which are essentially closed to commercial fishing because of excessive mercury contamination and the fish species which are contaminated.

Water Body	Fish Species Involved
Drunken Lake	Walleye
Laurie Lake	Northern Pike Walleye Lake Trout
Nelson River (Sipiwisk Area)	Northern Pike Walleye
Sipiwisk Lake	Northern Pike Walleye

four waterbodies in which the pike, walleye and/or lake trout are so highly contaminated that FFMC will not purchase the contaminated fish. These lakes and the fish species involved are listed in Table 2. Although the mercury problem constitutes an added burden to the northern commercial fishery, the quantity of fish withheld from market because of excessive contamination is relatively small. It is estimated that approximately 20,000 pounds (0.1% of the total Manitoba production) is rejected annually because of mercury (G. McGregor, pers. comm.).

Diversions and impoundments created by hydro-electric developments in northern Manitoba have also created problems for the commercial fishery. For example, the inundation of Southern Indian Lake has adversely affected the local commercial fishery because of increased mercury contamination in pike and walleye and increased Triaenophorus infestation in whitefish. The diversion of Churchill River flows to the Nelson River has virtually wiped out commercial fishing on Churchill River lakes downstream of Southern Indian Lake. Alterations of normal flow regimes on the Nelson River downstream of Lake Winnipeg have adversely affected fish reproduction in commercially fished lakes such as Cross Lake (Gaboury and Patalas 1982). Snags and debris from flooded shorelines also foul fishing nets and present boating hazards.

PART IV

ESTIMATED POTENTIAL STOCK ABUNDANCE (RESOURCE BASE)

Water Area in Manitoba

The first task in determining fish stock abundance is to outline the amount of available fish habitat. If is generally reported that approximately 101,600 km^2 (40,000 mi^2) or 16 percent of Manitoba's surface area is water (Statistics Canada 1981). About one third of this water area, or 33,550 km^2, is accounted for by the major lakes, lakes Winnipeg, Winnipegosis and Manitoba. The remaining water area is primarily on the Precambrian Shield area in the northern and eastern parts of the Province.

As described in the Methods, the number of lakes was tallied from 1:250,000 scale maps and then grouped into three regions; north, north-central and south (Fig. 13). Boundary lines separating these regions were drawn along the 1:250,000 scale map grid for ease of reference. There were several reasons for the way in which the boundary lines were chosen. The primary reason is the boundary lines approximate the northern and southern limits of the coniferous forest zone in Manitoba (as illustrated by Weir 1960) which in turn is a reflection of transitional zones in geological and climatic conditions. Additionally, the southeastern portion of each boundary line roughly follows the margins of the Precambrian Shield zone. The division between the south and north-central regions is also the approximate jurisdictional boundary of the Manitoba Department of Northern Affairs

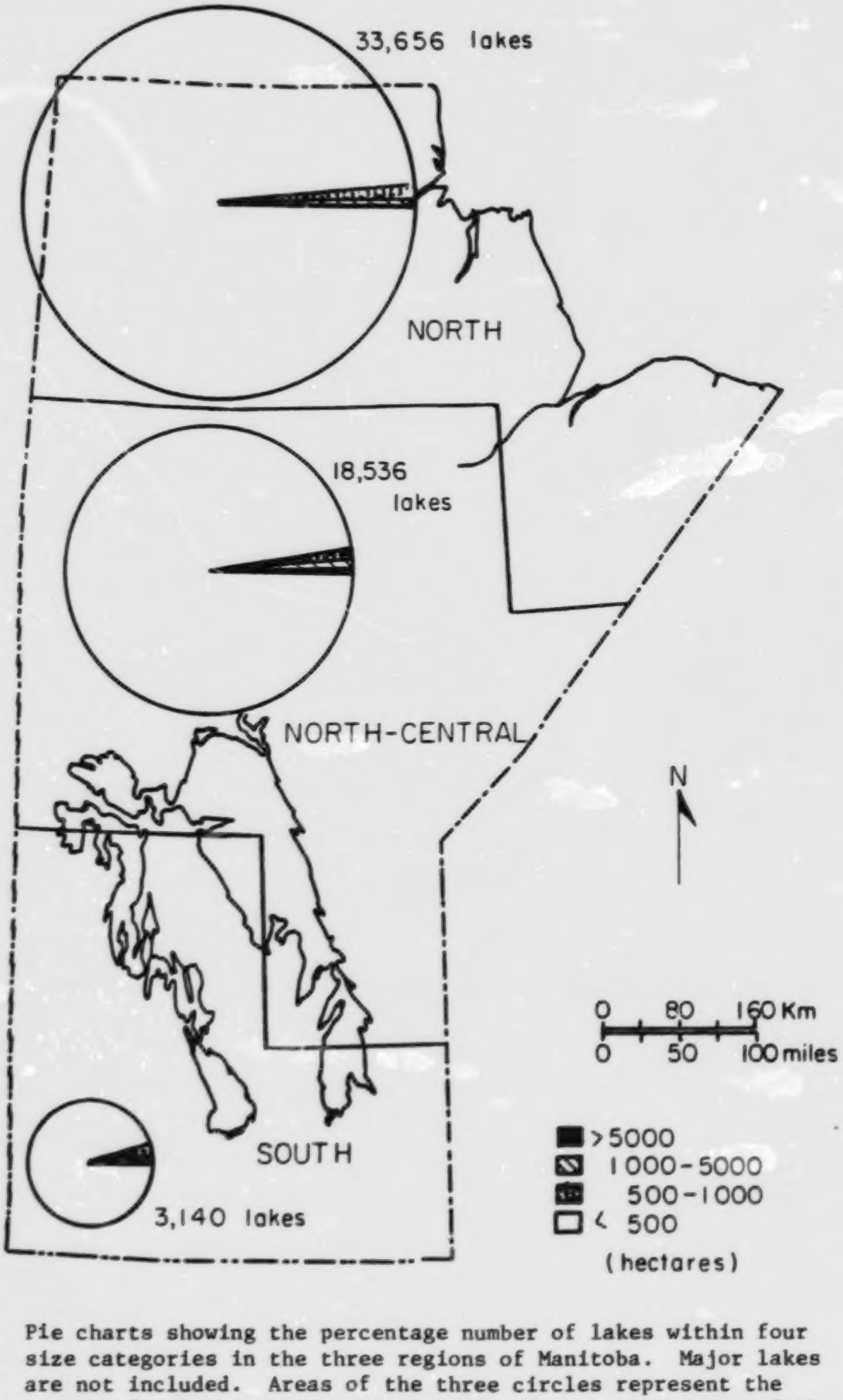

Fig. 13. Pie charts showing the percentage number of lakes within four size categories in the three regions of Manitoba. Major lakes are not included. Areas of the three circles represent the number of lakes in each region expressed as a percentage of the total number of lakes (55,332) in Manitoba.

and the approximate division line used by Fisheries Branch, Department of Natural Resources to classify southern and northern commercial fisheries. The boundary between the north-central and north regions approximates the limit of developed ground transportation routes within northern Manitoba.

The number and percentage of lakes in each size category within the three regions are presented in Table 3 and Fig. 13. Sixty-one per cent (33,656) of the waterbodies in Manitoba are situated in the most northerly portion. Almost all of the waterbodies in the northern region (98.6%) are smaller than 500 ha (1235 ac.). The north-central region contains 33.5 per cent (18,536) of the total number of waterbodies in the Province and most (97.4%) are also less than 500 ha in size (Table 3, Fig. 13). The south region accounts for only 5.7 per cent of the waterbodies and again most of these (96.1%) are less than 500 ha. Most larger lakes in the south are located in the southeastern corner of the Province. The greatest number of lakes (114) larger than 5000 ha (12,350 ac.) are found in the north-central region.

The tallying of lakes within the four size categories was a rather hastily executed procedure and could have been done with greater precision. If larger scale maps had been used, there might have been a much higher count of lakes smaller than 500 ha. Aerial photographs might also have provided an estimate of the number of waterbodies too shallow to support a population of large fish on a year-round basis. For future revisions of this report, satellite imagery may be available

Table 3. Number of lakes in various size categories in three regions of Manitoba.

Size category (ha)	Region			
	North	North-central	South	Total
>5000	48	114	16	178
1000 - 5000	108	157	43	308
500 - 999	316	218	65	599
<500	33,184	18,047	3,016	54,247
Total	33,656	18,536	3,140	55,332

Table 4. Comparison of count of lakes >500 ha in northern Manitoba in present study with inventory of other investigators.

Size category (ha)	Present study	Wickstrom and Merner (1970)	Sunde (1965)
>5000	162	127	109
1000 - 5000	265	222	264
500 - 999	534	60	100
Total	961	409	473

for more accurate counts and may provide more details on lake morphometry and water chemistry. In so far as the larger lakes are concerned, the counts are believed to be accurate as they compare favourably to data reported by Sunde (1965) and Wickstrom and Merner (1970) (Table 4). The counts do not entirely agree, however, since Wickstrom and Merner (1970) considered only commercially fished lakes, while Sunde (1965) did not include lakes on the east side of Lake Winnipeg and unnamed lakes.

Total water area for each size category of lakes within each region is presented in Table 5 and depicted as percentages in Fig. 14. The total area of lakes smaller than 500 ha in the north and north-central regions was approximately 4.1 million hectares. The total area of a number of northern Manitoba lakes listed by Sunde (1965) and later revised by Schlick (1977) was about 3.1 million hectares. Some lakes in this listing (67 out of 544) were less than 500 ha in area. In total, however, estimated areas in Table 5 appear to be within a reasonable range when the total water area in Manitoba is considered.

Total water area as determined in Table 5 (7.8 million ha) plus the water areas of the three major lakes provides a grand total surface area of 111,721 km^2 or approximately 11.2 million hectares of water surface in Manitoba (Table 6). This area represents about 17 per cent of Manitoba's total area. This figure is slightly higher than the 16 per cent reported by Statistics Canada (1981). Our figures could still be higher since a number of waterbodies less than 500 ha were undoubtedly deleted because of their small size.

Table 5. Estimated water areas (in hectares*) of lakes in various size categories in three regions of Manitoba.

Size category (ha)	Region			
	North	North-central	South	Total
>5000	576,000	1,368,000	192,000	2,136,000
1000 - 5000	324,000	471,000	129,000	924,000
500 - 1000	221,200	152,600	45,500	419,300
<500	2,654,700	1,443,700	241,300	4,339,700
Total	3,775,900	3,435,300	607,800	7,819,000

* Numbers have been rounded off to nearest 100 ha.

Table 6. Estimated total surface area of freshwater in Manitoba (excluding rivers).

Lake	Water Area
	hectares
Winnipeg*	2,376,000
Winnipegosis*	516,400
Manitoba*	460,700
From Table 5	7,819,000
Total	11,172,100

* excludes island areas.

Lake Winnipeg, Lake Winnipegosis and Lake Manitoba areas from Inventory of Canadian Freshwater Lakes by Canada Department of Environment Water Resources Branch (1973).

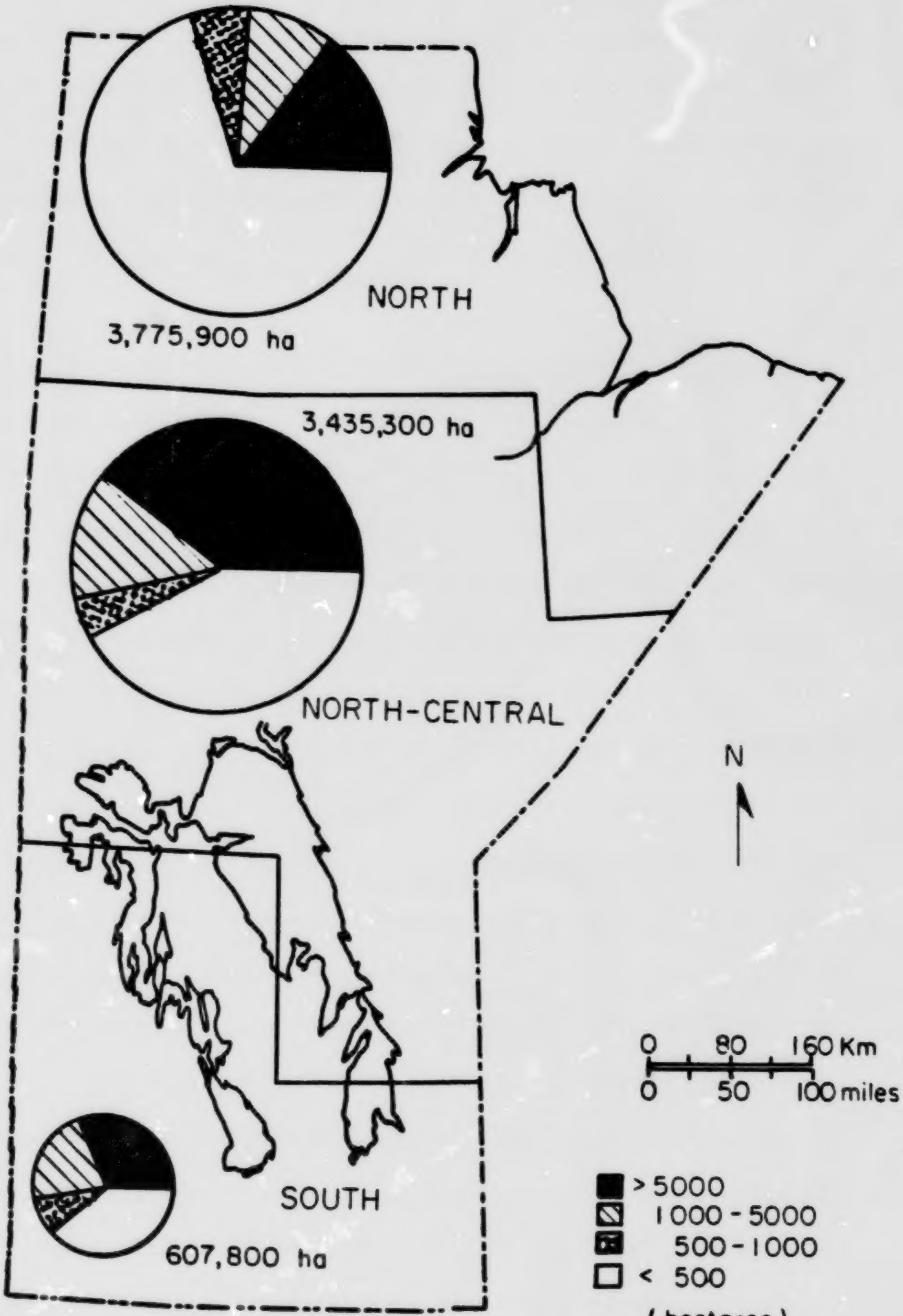

Fig. 14. Pie charts showing the percentage area of lakes within four size categories in the three regions of Manitoba. Areas of the three circles represent the total area of lakes in each region expressed as a percentage of the entire surface water area in Manitoba excluding lakes Winnipeg, Winnipegosis and Manitoba.

Knowing the approximate area of lakes in Manitoba, their size range and distribution throughout the Province, and their physical and chemical characteristics it is possible to derive a theoretical estimate of fish production potential for Manitoba's freshwaters within the three defined regions.

Estimation of Potential Fish Yields

It is generally considered that the capacity of a lake to produce fish is basically a function of both the lake's depth and the geology of its watershed. For example, relatively shallow lakes receiving large quantities of the primary nutrients (phosphates and nitrates) as well as other minerals from a surrounding sedimentary area will produce more fish per hectare than will deep lakes receiving runoff from a predominantly granitic area. This general principle has been applied by various fisheries scientists, notably Ryder (1965), to estimate the potential biological yields of lakes. Ryder's morphoedaphic index (MEI) and predictive equation were used to estimate fish yield potentials for primarily two reasons. First, the MEI could be applied to the limited amounts of information contained within many lake survey reports on Manitoba waters. Secondly, the MEI and corresponding predictive equation were particularly applicable to Manitoba since they were based on Precambrian Shield lakes within the same general latitudes as the majority of Manitoba's lakes.

Although fish yield potentials for a number of lakes have been estimated using the above method, the greater majority of Manitoba lakes have not been surveyed. Therefore, in order to indicate theoretical yields for most lakes, extrapolations were made using existing data from previous biological surveys and, to some extent, from past commercial production records.

Caution must be exercised in interpreting extrapolated data. It should be recognized that the fish production potential of northern lakes will be limited by climatic conditions. For example, a northern lake may be relatively shallow and receive an appreciable amount of nutrient loading, which would indicate high yield potential. However, these factors could render the lake subject to frequent winterkill conditions. Ryder _et al_. (1974) indicated that the most productive north-temperate lakes have mean depths ranging from 5-10 m. This is because north-temperate lakes less than 5 m deep are subject to winterkill conditions, while lakes with depths less than 10 m would generally allow primary production in a relatively large portion of the lake volume. Many northern Manitoba lakes are usually less than 2 or 3 m in mean depth. Therefore, estimates of potential yields from these waters are probably overestimates. Furthermore, northern lakes lying on the mainstream of such rivers as the Churchill and Nelson may have different productive potentials than the tributaries. Because the Churchill and Nelson rivers originate in the south, the thermal regime and chemical constituents of their waters will differ from those of their more northerly tributary waters.

Local geological conditions may also affect the productivity of some lakes. Lakes situated in areas of localized glacial lacustrine deposits, for example, will have a higher productivity than nearby lakes lying in predominantly granitic areas. However, caution should also be exercised when dealing with what appears to be highly productive areas because of large MEI values. Ryder _et al_. (1974) determined an optimum range for MEI seemed to be between 40-100, providing MEI components were at or near optimum. They mentioned that overestimates may occur when the MEI exceeds 100, because of high concentrations of ions (eg. sulphates and chlorides) that are essentially unrelated to fish production.

Finally, it must be stressed that the MEI approach was used only to give an indication or theoretical value of fish production from most Manitoba waters. Because of the numerous lakes, especially in northern Manitoba, only a small portion have been individually surveyed (Appendices III, IV, V). Those lakes that are surveyed are usually some of the larger lakes, more accessible to commercial or sport fishermen. In determining the theoretical value of fish production, it had to be assumed that unsurveyed lakes had limnological features similar to those surveyed lakes located in the same general area. A means for measuring the validity of theoretical yields is actual harvest values (Appendices VI, VII, VIII). The best measure of potential is the actual fish yields of lakes which have been subjected to intensive fishing pressure over a long period of years. However, a major problem with actual yield values from northern Manitoba lakes is that consistent long term production data are not available. Also, fishing effort may not have been intensive enough to produce a maximum sustainable yield. Past production records were used to determine potential yields from the major lakes; Winnipeg, Winnipegosis and Manitoba. This was possible since the three lakes have been intensively fished for at least a 31-year period (1950-1980).

Northern lakes

Most of the lakes that have been surveyed in northern Manitoba lie in the north-central region, between the 53rd and 57th parallels (Appendix III). This is also the general area in which many of the commercial fisheries in northern Manitoba occur. Lakes in the north region commonly possess potential yields in the range of 3 to 5 kg ha^{-1}yr^{-1}, while those in the north-central region are usually in the 5 to 10 kg ha^{-1}yr^{-1} range (Appendices III, IV). Average estimated yield potentials, grouped according to the 1:250,000 map grids, are higher in the north-central region than in the north region. Average yield potentials of north-central lakes varied from 2.9 to 11.7 kg ha^{-1}yr^{-1} and those in the north from 2.8-4.5 kg ha^{-1}yr^{-1} (Fig. 15). In some grids in the north-central region; the average potential yield exceeded 7.0 kg ha^{-1}yr^{-1}. The highest averages were generally in the southwestern part of the region.

In six specific instances, the estimated fish yield potentials from individual lakes exceeded 9.0 kg ha^{-1}yr^{-1} (Table 7). All six of these lakes are shallow ($\bar{z} = 1.5 - 3.5$ m) and, except for Kiskitto and Pearson lakes, all have TDS levels exceeding 200 mg l^{-1}. Fairly high TDS levels in Goose, Talbot and William lakes relate to their location in limestone deposits in the southwestern corner of the north-central region. Other lakes in this area have equivalent TDS levels (Fig. 16), but have lower yield potentials because of greater mean depths. Even though Ted and Pearson lakes are located in predominantly granitic areas, both are extremely shallow and situated in areas with localized clay deposits.

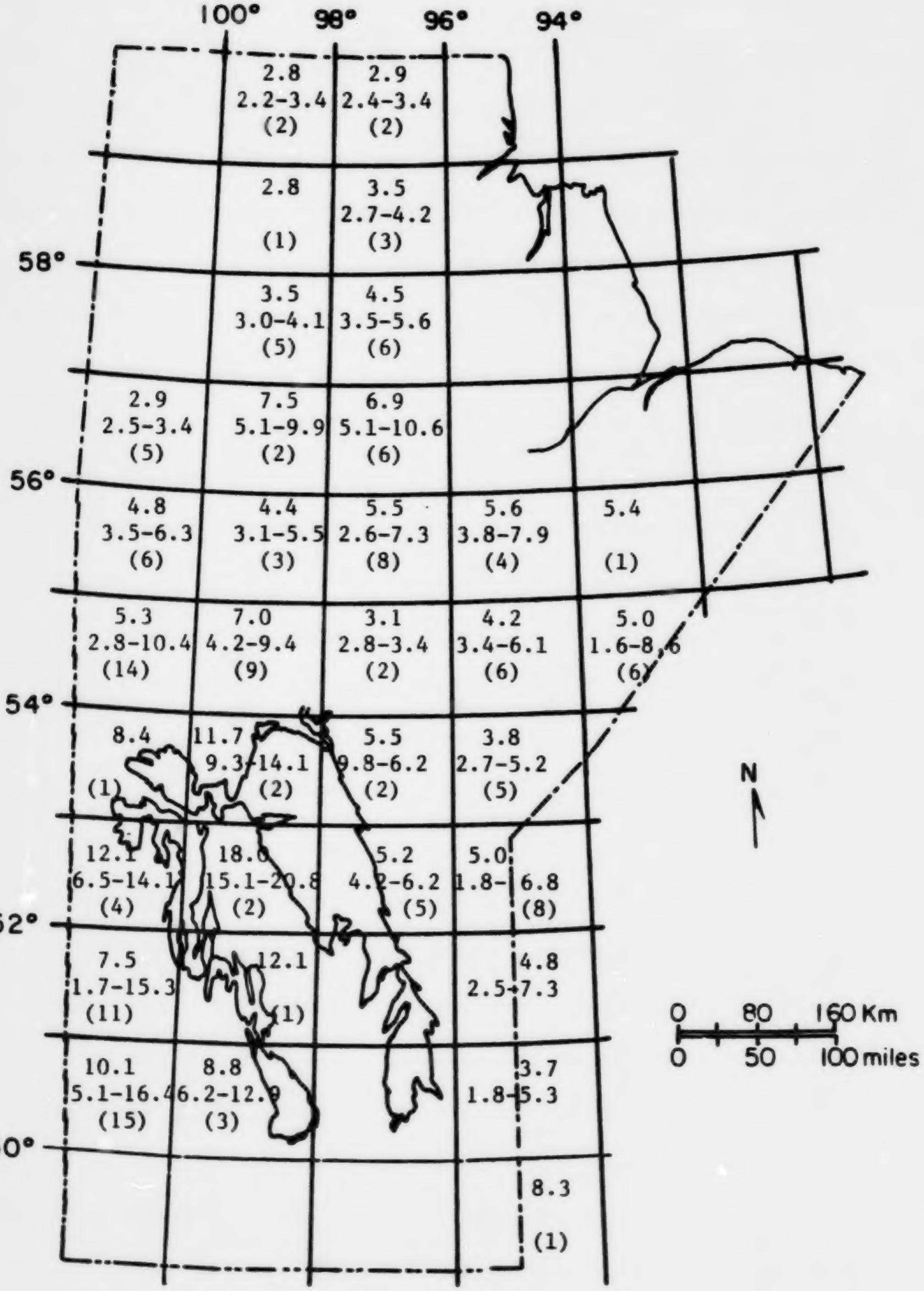

Fig. 15. The average and range in theoretical fish yields in kg ha^{-1} of lakes in Manitoba. Number of lakes on which averages are based are given in parentheses.

Table 7. Northern Manitoba lakes with estimated yield potentials >10 kg ha^{-1}.

Lake	Location		Estimated yield kg ha^{-1}
	Lat.	Long.	
Ted	56°30'	99°40'	9.9
Pearson	56°15'	97°15'	10.6
Goose	54°28'	101°30'	10.4
Talbot	54°00'	99°55'	14.1
William	53°54'	99°21'	9.3
Kiskitto	54°16'	98°30'	9.4

Table 8. Manitoba lakes in the north and north-central regions with fish yields $\geq$ 7 kg ha^{-1}yr^{-1}.

Lake	Yield kg ha^{-1}	Area (ha)	No. of years fished
Cedar	7.20	124,147	5
Denison - Mackerracher	9.66	3,870	1
Dow	6.96	886	1
Hill	9.03	1,048	1
Rat East	8.58	2,742	3
Simpon - Swede - Ellystan	7.85	370	1
Soloman	7.80	780	3

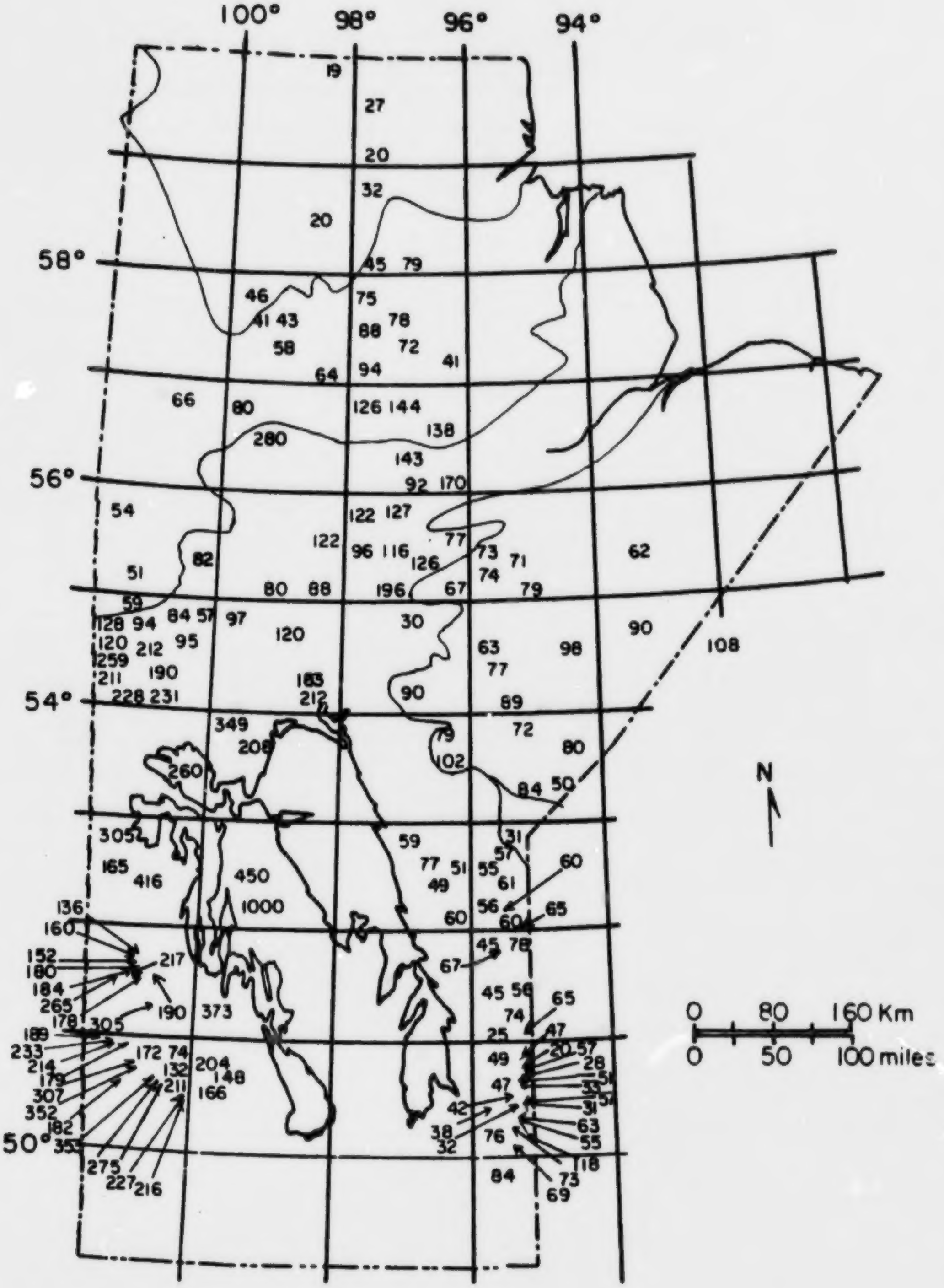

Fig. 16. Total dissolved solid levels (TDS) in mg ℓ^{-1}) marked in appropriate location of lake in which they occur. The major drainage basins in Manitoba are delineated. See Appendix II for lake name and location.

Lakes in the eastern portion of the north-central region had slightly lower yields than those further west around the Wabowden area (Fig. 15). This difference might be explained by the extensive clay deposits left in the Thompson-Wabowden area following the retreat of Glacial Lake Agassiz. According to Weir (1960), localized clay deposits occurred between 96° and 100° longitude and as far north as the edge of the Nelson River Drainage Basin boundary (approximately 56°30'). The effects of these lacustrine clay and silt deposits are reflected in TDS levels in lakes. TDS concentrations in lakes situated on the Precambrian Shield in areas of localized clay and silt deposits are higher than in lakes in the eastern part of the north-central region where the geology is typically granites (Fig. 16).

Although only 20 lakes have been surveyed in the north region, it is evident that waters in this area are less productive than those in the north-central region (Fig. 15). Estimated yield potential from most of these lakes is generally less than 4 kg $ha^{-1}yr^{-1}$ (Appendix III). However, eight of the northern lakes have potential yields in excess of 4 kg $ha^{-1}yr^{-1}$. All of these lakes, except Whitefish Lake, are located within the Churchill River Drainage Basin in the south-central portion of the north region. Whitefish Lake is located further south at a similar latitude to many north-central lakes (lake no. 168, Appendix II). Average estimated yield potentials were lower in the most northerly areas of the north region (Fig. 15). This was partially due to low TDS levels in these areas as compared to higher TDS levels from lakes in the Churchill River drainage system (Fig. 16).

Further indications of the potential yields from northern lakes can be derived from an examination of actual fish yields from commercially exploited lakes (Fig. 17). Commercial fishing information on individual lakes is presented in Appendices VI, VII and VIII. Data presented on actual harvests were abstracted from the Manitoba Fisheries Fact Book. Commercial catches presented in this document are based on the period 1976-1980, since all production records during this period were expressed in round (whole) fish weights. Production data prior to 1976 were recorded as marketed weights; i.e. weights were recorded when the fish were headless-dressed, dressed or in round form.

It is quite apparent that actual harvests were lower than estimated yield potentials. Examination of Fig. 17 reveals that the north-central region lakes, on average, produced more fish per unit area than lakes in the north region. Average yields from north-central lakes were generally 2.5-3.0 kg $ha^{-1}yr^{-1}$. Yields from lakes in the north region were usually around 1-2 kg $ha^{-1}yr^{-1}$ (Fig. 17). Lakes with exceptionally high yields (7-10 kg $ha^{-1}yr^{-1}$) were observed in both regions (Table 8). It will be noted that most of these high yields came from lakes smaller than 5000 ha. Lakes smaller than 5000 ha can be more effectively fished than larger lakes; i.e the concentration or density of fish in smaller lakes is greater and therefore less searching is required and fish are more easily captured. The good yields from larger lakes, such as Cedar Lake, are due mainly to their good productive potential, convenient access and the amount of fishing effort expended on each lake.

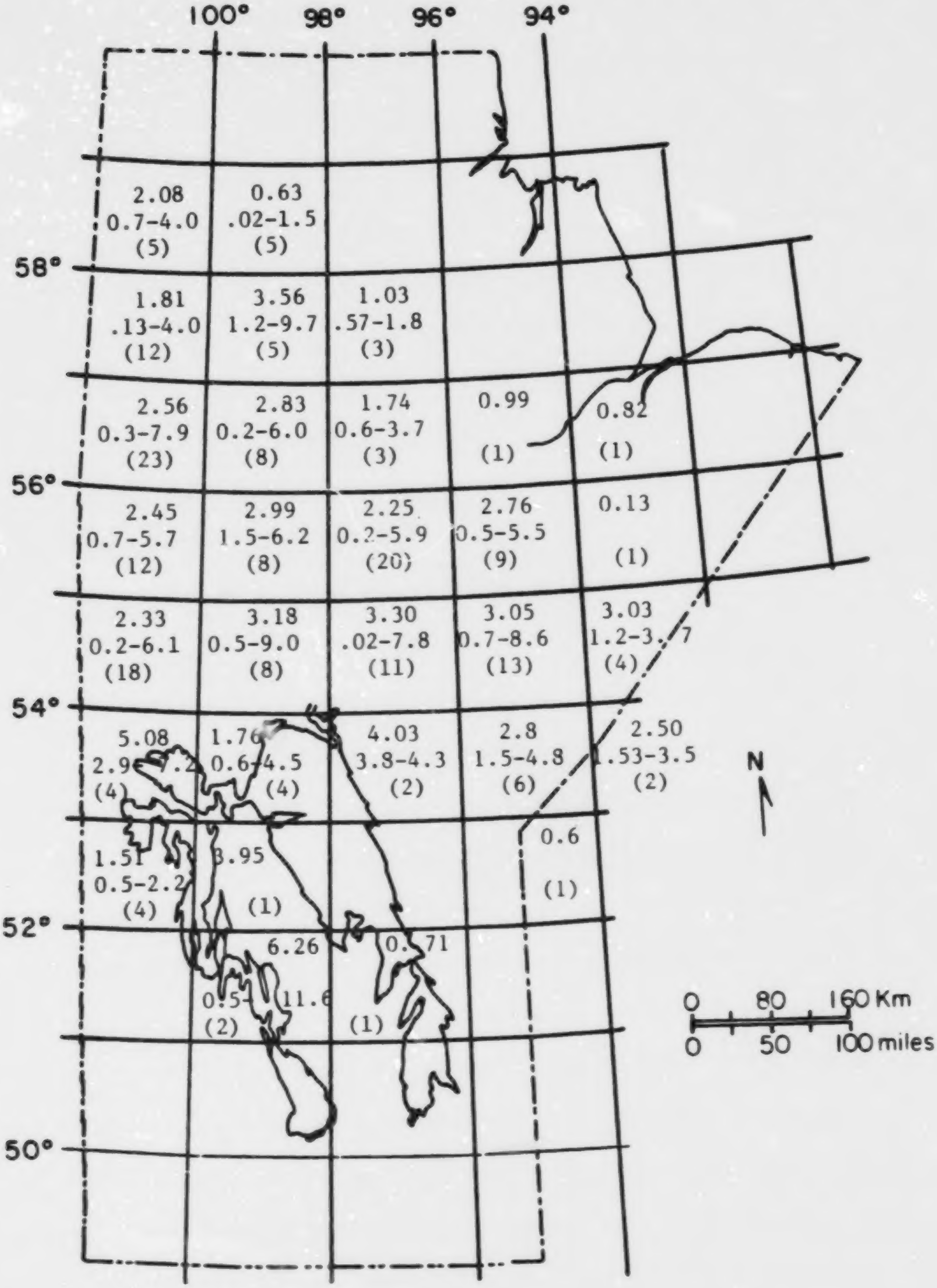

Fig. 17. The average and range in actual fish yields in kg ha^{-1} of commercially fished lakes in Manitoba. Numbers of lakes on which averages are based are given in parentheses.

As previously stated, climatic conditions will also greatly influence the productivity of lakes. A crude indication as to the influence of climate on fish production can be seen by superimposing the July isotherms (Fig. 18), January isotherms (Fig. 19) and frost-free days (Fig. 20) on the actual yields as illustrated in Fig. 17. Average yields from lakes in zones located in warmer areas were generally better. For example, lakes situated between the 13C (56F) and 14.5C (58F) July isotherms produced an overall average yield of about 1.5 kg $ha^{-1}yr^{-1}$. In contrast, average yields between the 14.5C and 16.7C (62F) and between the 16.7C and 18.3C (65F) July isotherms approximated 2.4 and 2.7 kg $ha^{-1}yr^{-1}$, respectively.

The northern limit of yellow perch in Manitoba, as described by Scott and Crossman (1973) and delineated on Fig. 18, lies between the 13C and 14.5C July isotherms. Higher summer temperatures, however, are required to provide favourable or optimum conditions for yellow perch. According to Hokanson (1977), mean summer (late July-early August) temperatures around 16C represent the lower temperature envelope for yellow perch. The northern limit for yellow perch also probably represents the northern limit for commercially exploitable walleye populations. Although walleyes have been caught in areas north of the 13C isotherm (near the mouth of the Churchill and Seal rivers), they are not present in large numbers. The largest catches of walleyes from lakes lying between the 13C and 16.7C isotherms come from lakes on the Churchill River. The presence of large walleye populations in the Churchill River lakes may be attributable to the higher temperatures of the waters, which originate in more southerly latitudes. The Churchill

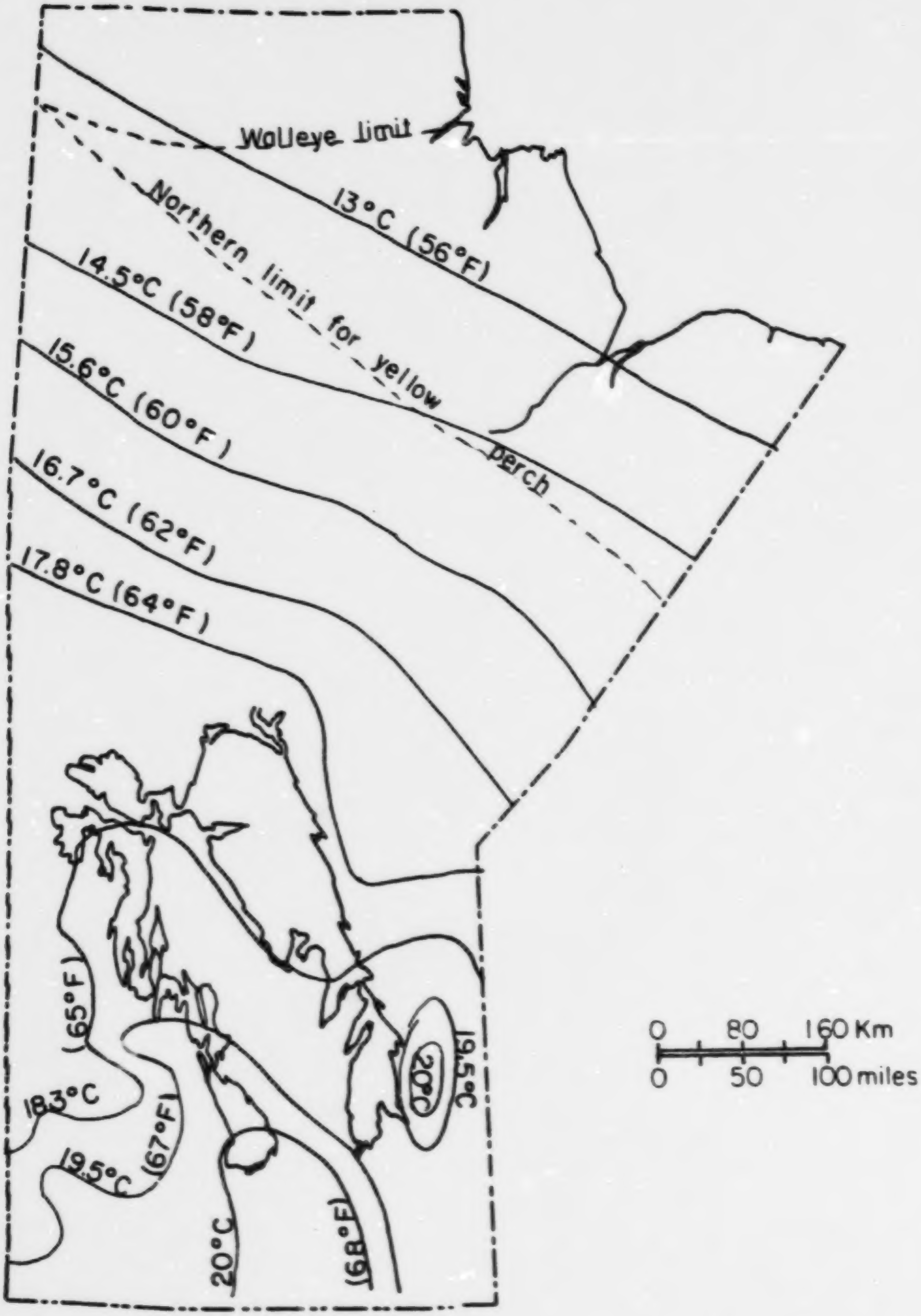

Fig. 18. A map of Manitoba showing the July isotherms (from Weir, 1960) and the approximate northern limit of walleye and yellow perch distribution in Manitoba.

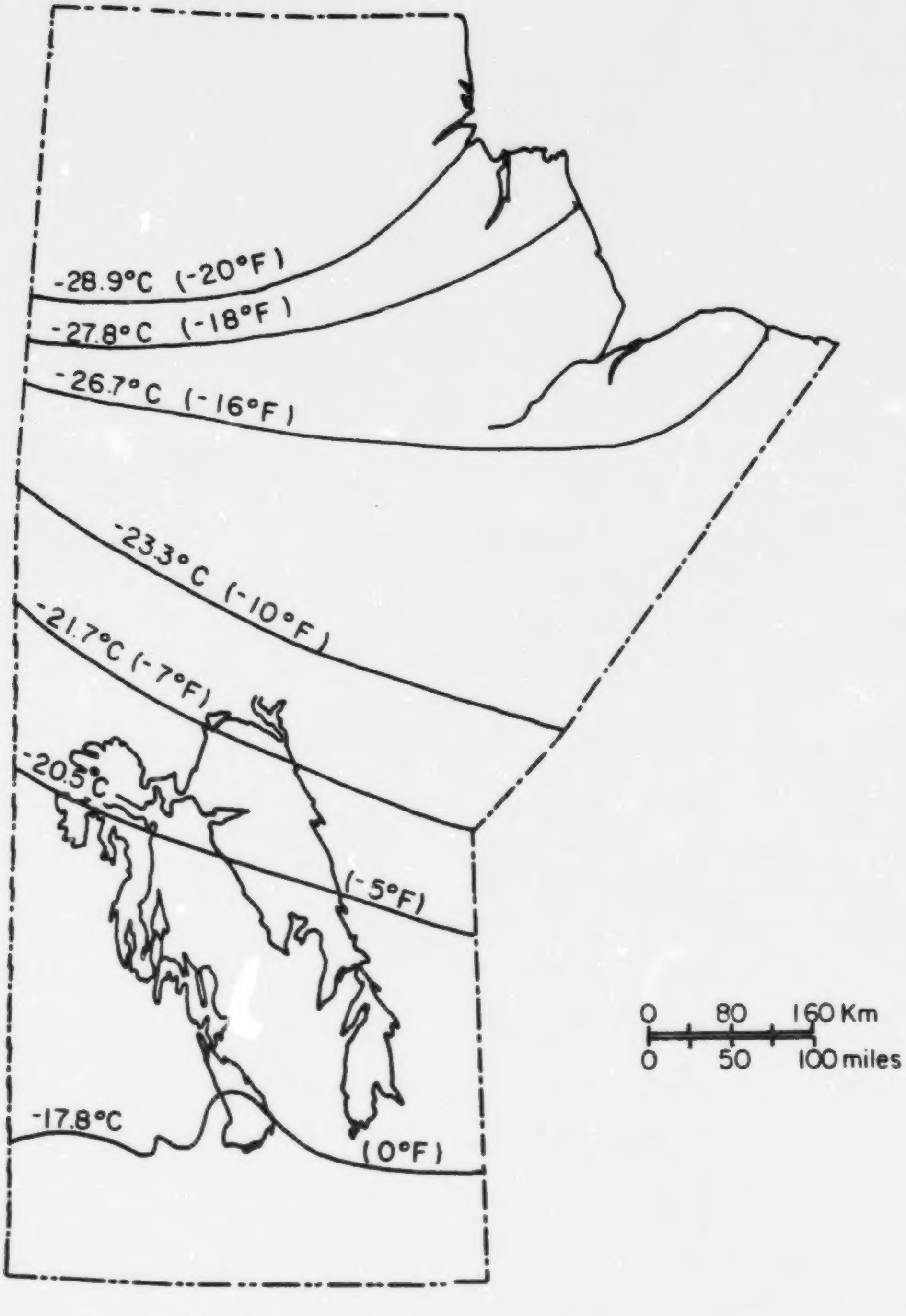

Fig. 19. The distribution of January isotherms in Manitoba (from Weir, 1960).

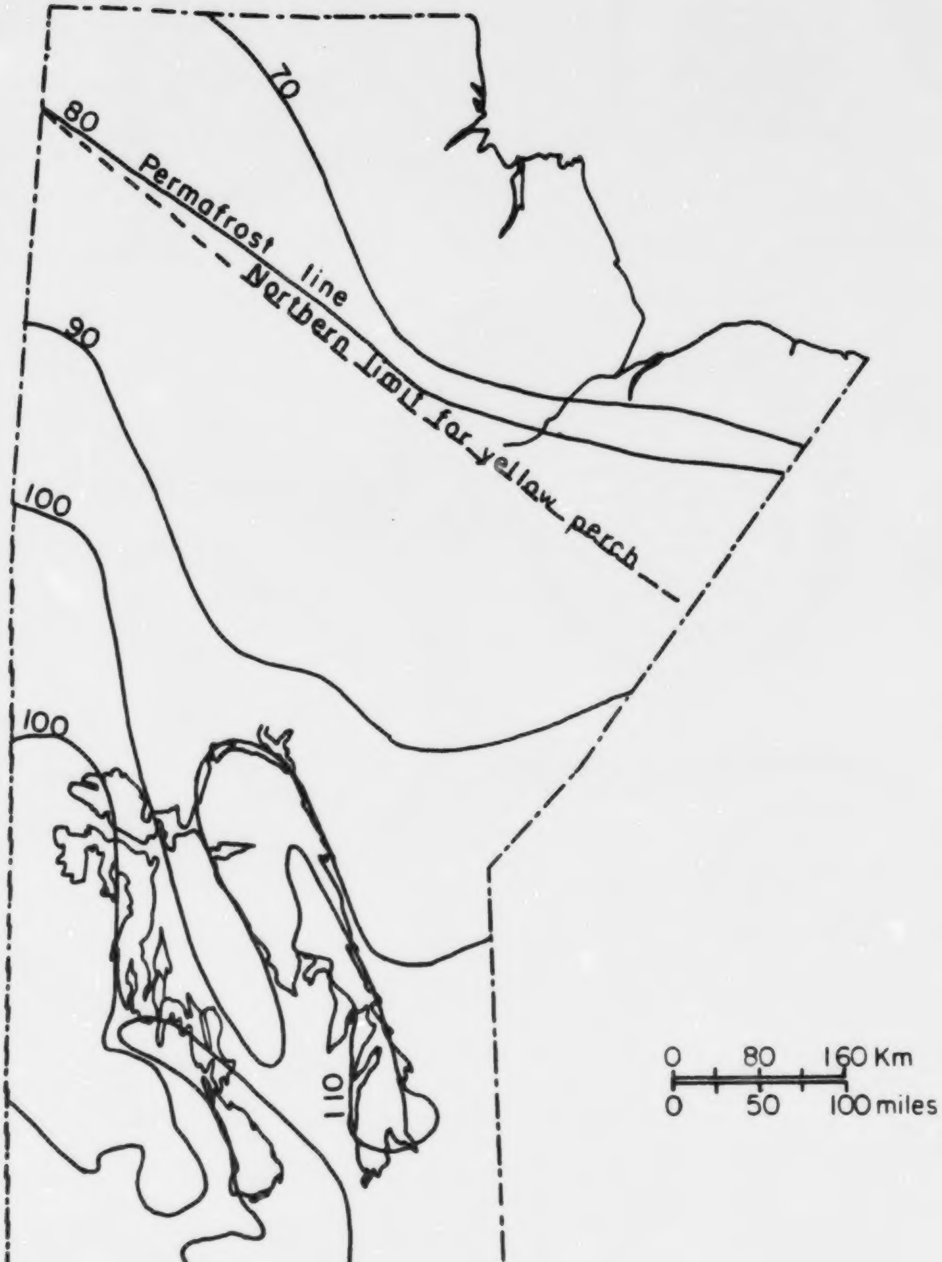

Fig. 20. A map of Manitoba showing the number of frost free days in the province (from Weir, 1960) and the northern distributional range of yellow perch relative to the permafrost lane.

River around Southern Indian Lake also supports sauger populations, but this species is much less abundant than walleyes. On the basis of observed distribution of large percids (walleye, sauger and yellow perch) in northern Manitoba, the 16.7C July isotherm likely represents the northern limit at which walleye populations may be reasonably successful. Walleye populations north of the 16.7C isotherm may be generally considered as marginal and easily subject to overexploitation.

Although summer temperatures are crucial in determining population success of such spring-spawning species as walleye and northern pike, the effects of winter temperatures and frost conditions can be especially important to the overwintering of fish in shallow ($\bar{z} <$ 5m) northern lakes. Prolonged periods of colder temperatures can increase ice thickness, thus reducing habitat space in winter and shortening the summer growth period. Winter temperatures and frost conditions may also affect the distribution and abundance of "warmwater" species. The -23.3C (-10F) January isotherm and the line representing 90 frost free days are similar to the 16.7C July isotherm. It should also be noted that the permafrost line approximates the northern limit of yellow perch in Manitoba (Fig. 20).

Comparison of theoretical and actual yields, as presented in Figs. 15 and 17, shows that actual yields were near the theoretical yields in a few cases, but were usually lower. On two lakes, actual production equalled or superceded theoretical yields. These were on MacBride Lake and White Rabbit Lake (Appendices IV and VII).

When considering the relationship between actual and theoretical yields, it is important to recognize that actual yield statistics include only landed catches which consist of desirable quota species (whitefish, walleye, pike, sauger and lake trout). Sauger and lake trout represent only a small portion of the total landed catches from the north and north-central regions. Much of the catch of non-quota or coarse fish species (suckers, yellow perch, tullibee, etc.) are not included in the actual or recorded yields. To some extent, portions of whitefish and pike catches from northern lakes are also not recorded. These species are sometimes discarded or "bushed" because market prices for these species are too low in comparison to transportation costs in the north.

A better comparison between actual and theoretical yields was apparent when the theoretical yields were reduced by the appropriate percentage of coarse fish taken in commercial fishery gillnets. Based on the species composition of experimental catches, this meant reducing the theoretical yields for Manitoba lakes by an average of 40 to 50 per cent. This procedure had seemed appropriate at the time because of our initial interpretation of information presented by Ryder et al. (1974). They indicated that the total potential yield of a lake was more a function of primary productivity and was not appreciably affected by specific trophic levels of production. Ryder (1965) had noted that even though the species composition of fish communities changed in some lakes, ultimate yields remained fairly constant since the removal of fish at one trophic level is usually compensated for by the interaction of other species at other trophic levels. From this, we assumed that the MEI formula could be applied to all large species of fish. However, Colby et al. (1982) questioned including in the MEI yield, fish species which were not part of the original MEI derivation by Ryder (1965). One such group of fish was suckers. Suckers form a major portion of non-quota fish caught in Manitoba.

Colby et al. (1982) recommended guidelines for partitioning the potential yields, as estimated by Ryder's (1965) method, into individual species yields. This approach to partitioning yields from Manitoba waters provides results which were similar to results derived by deducting the percentage of non-quota species observed from experimental gillnet catches. Sixty per cent was used as a general partitioning figure for Manitoba lakes (Table 9). This value represented partitioning of species caught mainly in the sport and commercial fisheries and was similar to the percentage of quota species normally caught in gillnets. Colby et al. (1982) recommended catches of whitefish, walleye and northern pike by a commercial fishery be between 54 and 64 per cent of the estimated potential yield. As noted earlier, these three species comprise the major portion of landed catches from northern Manitoba lakes. The recommended partitioning of game fish species in Manitoba, namely pike and walleye, amounts to about 57 per cent of the MEI derived yield. Pike and walleye form 90 to 95 per cent of angler catches in Manitoba according to angler surveys conducted in 1975 and 1980. It must be emphasized that these are general observations relating to the majority of lakes in Manitoba. Even though lake trout, brook trout (Salvelinus fontinalis) and rainbow trout amount to a very small percentage of the overall catch,

Table 9. Potential yields of prime fish species from lakes in the north, north-central and southern regions using a partitioning factor of 60%.

Region	Yields (kg ha^{-1} yr^{-1})	
	Total potential*	60% of potential
North	3.7	2.2
North-central	5.3	3.2
South	7.8	4.7

* Total potential yield for each region was determined by averaging potential yields of individual lakes as listed in the Appendices.

Table 10. Total MEI potential yield for lakes in the north, north-central and south regions of Manitoba. Figures in parentheses are potential yields after non-productive waterbodies <500 ha have been excluded[1].

Size category (ha)	Total potential fish yield			(kg)
	North	North-central	South	Total
>5000	2,131,200	7,250,400	1,497,600	10,879,200
1000 - 5000	1,198,800	2,496,300	1,006,200	4,701,300
500 - 999	818,400	808,800	354,900	1,982,100
<500	9,822,400 (5,893,400)	7,651,600 (5,738,700)	1,882,100	19,356,100 (13,514,200)
Total	13,970,800 (10,041,800)	18,207,100 (16,294,200)	4,740,800	36,918,700 (31,076,800)

[1] Estimated percentages of non-productive waterbodies were 40 and 25 percent in the north and north-central regions, respectively.

these species are the dominant species in the fish communities of a few lakes.

Partitioning of the potential yields from the north and north-central regions resulted in approximate yields of prime species of 2.2 and 3.2 kg $ha^{-1}yr^{-1}$, respectively. Based on commercial fishing records, some lakes in portions of the north-central region have been producing near, at or perhaps even beyond their theoretical capacity. This does not, however, imply that severe overfishing has generally occurred throughout the north. Most lakes in northern Manitoba have not had a long history of commercial exploitation. A marked expansion in the northern commercial fisheries did not occur until about 1955. Also, fishing on many of the northern lakes has only been intermittent. Even though some lakes might have been overexploited in one or several years, the intermittent fishing could have allowed fish stocks sufficient time to recover. However, isolated instances of overfishing on individual lakes undoubtedly exist (eg. Sisipuk Lake).

Commercial yields from lakes in the north region are usually below the partitioned MEI potential yield. This is probably because of decreased fishing effort, resulting from greater increases in operating costs and reduced profit margns, as well as MEI potential yield estimates which are too high. Several of the lakes which have been surveyed in the north region have mean depths below 5m. Some of the lakes with the highest potential yields are extremely shallow. They have mean depth less than 3m (Appendix III). These shallow waters have high theoretical yields, but actual yields are probably lower. The level of productivity of these lakes is likely severely limited because of the rigorous winter conditions.

Using the total potential yield rations given in Table 9 and the estimated water or lake areas in the north, north-central and south regions, the total potential fish yield for Manitoba freshwaters, exclusive of the three major lakes, is approximately 37 million kg (Table 10). Most of this potential (18 million kg or 49%) occurs in the north-central region. If only the prime or quota species are considered, the potential harvest for the three regions (exclusive of three major lakes) is approximately 22 million kg (Table 11). Fifty per cent of this potential is again found in the north-central region. By comparison, the southern region as a whole has a low potential for fish production. This is due to fewer lakes in the south. Estimated yield potentials from the southern region are considered liberal since most of the waterbodies are extremely shallow and small in size. Many of the southern waters are not able to support sustained angling pressure and require periodic stocking.

It should be noted that slightly more than 47 per cent of the estimated fish production potential, or 17.5 million kg, comes from northern Manitoba lakes smaller than 500 ha. Many of these lakes, particularly those less than 100 ha, may not be capable of producing fish on a continual basis because of winterkill conditions or lack of adequate fish habitat. Unfortunately, very few of the myriad of small lakes in northern Manitoba have been surveyed and their productive

Table 11. **Partitioned theoretical fish yields (kg yr^{-1}) from the north, north-central and south regions in Manitoba. Figures in parentheses are potential yields after non-productive waterbodies <500 ha have been excluded[1].**

Size category (ha)	Partitioned potential MEI yield (kg yr^{-1})			
	North	North-central	South	Total
>5000	1,267,200	4,377,600	902,400	6,547,200
1000 - 5000	712,800	1,507,200	606,300	2,826,300
500 - 999	486,600	488,300	213,900	1,188,800
<500	5,840,300 (3,504,200)	4,619,800 (3,464,900)	1,134,100	11,594,200 (8,103,200)
Total	8,306,900 (5,970,800)	10,992,900 (9,838,000)	2,856,700	22,156,500 (18,665,500)

[1] Estimated percentage of non-productive waterbodies were 40 and 25 percent in the north and north-central regions, respectively.

Table 12. Percentage contribution of three major fish species to the northern Manitoba commercial fishery, based on the species composition of the average annual catches for the period 1950 - 1980. This species composition is used to determine the potential yield of prime or quota species from northern lakes.

Species	% Composition[1]	Estimated yield (kg)[2]
Whitefish	58	5,104,000
Walleye	24	2,112,000
Northern Pike	18	1,584,000

[1] Percentage reflect relationship between the three major species alone.

[2] Total potential yield of prime or quota species from northern lakes of 8.8 million kg.

capacity is virtually unknown. Small lakes associated with a river or stream system may be more likely to support fish populations. Even if such lakes winterkill, they may be replenished by fish from other parts of the drainage system. In the case of totally enclosed lake basins, replenishment by natural means following winterkill is virtually impossible. Enclosed lake basins are most common farther north. As a guess, it is estimated that about 40 per cent of the lakes in the north region and 25 per cent in the north-central region are incapable of producing fish on a sustained basis. Deducting the potential of these non-productive waters, the total potential of northern lakes is 26.3 million kg; 10.0 million kg in the north and 16.3 million kg in the north-central regions (Table 10). Considering that only 60 per cent of the yields may consist of prime fish species, the total productivity of northern lakes is in the order of 15.8 million kg (Table 11). Of this amount, 7.0 million kg comes from small lakes. The greatest potential (9.8 million kg) is in the north-central region.

At present, many of the small lakes (<500 ha) lie in areas not serviced by roads or railways. Because of their small size, many are not large enough to land an aircraft on and are therefore inaccessible by air. The fisheries potential of these small waterbodies is thus effectively locked up until a road network is developed. Since extensive road development in northern Manitoba is unlikely within the foreseeable future, present production potential for northern lakes should not include the potential yields from lakes less than 500 ha. A realistic estimate of present fish production capacity of north and north-central Manitoba lakes is, therefore, in the order of 14.7 million kg of all species and 8.8 million kg if only the prime species are considered. The latter estimate (8.8 million kg of prime species) is 33 per cent higher than a similar estimate derived by Adams *et al*. (1976). They estimated, by totalling the existing quotas on all commercially fished lakes in northern Manitoba, that the potential production of all species was 15.1 million kg of which 6.6 million kg were quota species. These estimates were lower than our results because Adams *et al*. (1976) based their estimates on a fewer number of lakes. They had identified a total of 672 lakes. This is 30 per cent less than the 961 lakes greater than 500 ha used for our estimates. It should be emphasized that our potential production figures should be considered as only "ballpark" estimates, since they are based on rather broad generalities which do not fully consider variations in environmental and geological conditions around individual lakes.

Over the past three decades (1950-1980), whitefish and walleye have formed the highest proportion of fish landed from northern Manitoba (Table 12). An indication of potential landings of whitefish, walleye and northern pike might be derived by applying the species composition based on previous production records to the potential yield of prime or quota species only. This analysis indicates potential harvests of approximately 5.1 million kg of whitefish, 2.1 million kg of walleye and 1.6 million kg of northern pike (Table 12).

Southern lakes

The average potential yield of waters from the southern region was found to be approximately 7.8 kg $ha^{-1}yr^{-1}$. Many of the lakes in southern Manitoba are situated in the southeastern corner of the Province on the Precambrian Shield. Lakes in that area have an average potential yield of 4.0 kg $ha^{-1}yr^{-1}$ (Fig. 15, Appendix V). Greater MEI derived yields are observed for lakes farther west, such as Swan, Pelican (52°28', 100°20') and Waterhen lakes, which are situated in limestone topography. These lakes and others in the same general area have MEI estimated yields averaging around 14 kg $ha^{-1}yr^{-1}$ (Appendix V).

South-central and southwestern lakes have been considered to have yield potentials similar to Rock Lake, which has a potential production capacity of 12 kg $ha^{-1}yr^{-1}$. High MEI yield potentials for these lakes is partly due to their shallow depths and high nutrient loading from surrounding agricultural lands. The TDS concentration of Rock Lake has been reported to be 300 mg l^{-1} (Pederson and Andrews 1972). Average potential yields are lower for lakes located in and around the Riding Mountain and Duck Mountain areas. The potential yield of southern lakes with average depths greater than 3 m was about 7.0 kg $ha^{-1}yr^{-1}$ (Appendix V). With an overall average productivity of 7.8 kg $ha^{-1}yr^{-1}$ for southern lakes, the total production potential is about 4.7 million kg (Table 10). Again assuming that 60 per cent of the potential consists of prime or desirable species, the potential yield is then 2.9 million kg

(Table 11). The species composition of commercial catches from southern lakes over the 1950-1980 provide some indication of the possible percentage contribution of the prime species to the potential yield (Fig. 8). The quota managed species observed, in order of numerical importance, in the southern commercial fisheries are northern pike, walleye and whitefish.

The potential yield of commercially fished southern lakes is probably an overestimate. Observed or historic yields from southern commercial lakes were well below the 7.8 kg $ha^{-1}yr^{-1}$ level. The only exception was in the case of the Lake St. Martin fishery which had annual yields ranging from 7 to 18 kg ha^{-1} (Appendix VIII). The average yield in the grid section including Lake St. Martin was 6.3 kg $ha^{-1}yr^{-1}$ (Fig. 17). This figure, however, is misleading because of the extremely high average yield (11.6 kg ha^{-1} yr^{-1}) observed for Lake St. Martin. Reasons for this high yield from Lake St. Martin are not definitely known. It is speculated, however, that some fish caught in the Sturgeon Bay area of Lake Winnipeg have been reported on the Lake St. Martin landings since there has been no quota restriction placed on this fishery in the past.

The majority of commercially fished lakes in the southern region are located in the interlake and northwestern sections. Boundary lines used in this report differ slightly from those employed in the Department of Natural Resources Annual Reports; therefore, production statistics for some lakes such as Cedar, William and Family have been eliminated from the totals for the southern lakes and added to the north-central production totals. Consequently, production totals from the southern region lakes listed in this report are less than those found in the Department of Natural Resources Annual Reports.

Although commercial fishing occurs on some lakes, sport fishing is the main type of exploitation on most southern lakes. The primary game fish caught are walleye and pike. According to a 1980 sport fishing survey, about 2.3 million kg of these two species were harvested from southern lakes in that year. This value is similar to the 2.9 million kg (Table 11) yield of prime fish species estimated for southern lakes. This would suggest that the estimated potential yield is a fairly reasonable estimate. However, theoretical yields for many of the lakes in the southern region are thought to be excessive since a substantial number of southern lakes require annual or periodic stocking of game fish in order to maintain a sport fishery. Re-stocking is particularly necessary in the case of the smaller, shallower waterbodies which are prone to summerkill conditions brought on by high temperatures and excessive algae blooms or by winterkill caused by oxygen depletion.

The major lakes

Estimation of potential yields, using Ryder's method, for the three largest lakes in Manitoba, and particularly Lake Winnipeg, is somewhat more difficult than for northern or southern lakes. This difficulty arises because of the rather complex basin configurations and the consequent limnological diversities of these large lakes.

The south basin of Lake Winnipeg is relatively shallow and highly turbid. It receives the highest proportion of the lake's total inflow of surface water (Brunskill *et al*. 1980) and nutrients. Because of the high turbidity, much of the nutrient load to the south basin is not incorporated into the biological cycle. The north basin of Lake Winnipeg is deeper and less turbid than the south basin. The Channel Area, which separates the north and south basins, is a zone of extensive mixing. Although there is a net discharge of water from south to north, frequent northerly winds will push water from the north basin, through the Channel Area, and into the south basin (Kenny 1979). Lake Winnipeg may also be divided into east and west sections which differ limnologically. Chemical features of waters in the eastern section reflect the influence of the Precambrian Shield, whereas conditions typifying calcareous, sedimentary lakes prevail in the western portion (Rybicki 1967 and Kristofferson *et al*. 1975). Because of the lake's size and exposure to prevailing winds, waters in the eastern and western portions are frequently mixed during the openwater period. Because of the relatively shallow nature, water masses are usually well mixed vertically, but horizontal gradients of many chemical parameters and nutrient elements do occur (Brunskill *et al*. 1980). These horizontal gradients may disappear, however, after intense and prolonged wind action (Kristofferson *et al*. 1975).

It is generally agreed that the south basin and Channel Area of Lake Winnipeg are much more productive than the north basin. This is evident from the fact that the bulk of commercial catches come from the central portion and the south basin of the lake. Species composition of the catches also differ depending on the area of the lake in which the catches are made. Whitefish are primarily caught throughout much of the north basin, while sauger and walleye contribute the largest amount to catches from the south basin, Channel Area and south end of the north basin.

Lake Manitoba differs appreciably from Lake Winnipeg and also exhibits some unusual limnological characteristics. Unlike Lake Winnipeg which receives drainage from both sedimentary and Precambrian areas, drainage accruing to Lake Manitoba is totally from sedimentary areas. Therefore, concentrations of major ions are generally greater in Lake Manitoba than in Lake Winnipeg. TDS concentrations in Lake Manitoba are much higher than in Lake Winnipeg; average TDS levels exceeding 1000 mg l^{-1} have been recorded in Lake Manitoba (Cober 1968). These high TDS concentrations, particularly in the south basin of Lake Manitoba, have been attributed to groundwater additions from the underlying limestone and high evaporation rates. (International Garrison Diversion Study Board, Water Quality Report, 1976). TDS levels in the north basin of Lake Manitoba are not as high due to dilution by inflows from Lake Winnipegosis. The main inflowing stream, which contributes over 70 per cent of the gauged river inflow to the lake (Teller and Last 1979) and the lake's outlet are situated in the north basin. The completion in 1969 of the Assiniboine River Diversion into the south basin of Lake Manitoba introduced another complicating factor to the lake's water chemistry. The addition of more dilute waters from the Assiniboine River has brought about a "freshening" of southern Lake Manitoba. Since the Diversion is used to divert spring flood waters which contain heavy loads of suspended sediments, nutrient and sediment loads to Lake Manitoba have also been increased.

The limnological conditions of Lake Winnipegosis have not been as extensively studied as those of either lakes Winnipeg or Manitoba. Available limnological data on Lake Winnipegosis are mainly unpublished. Total dissolved solids in Lake Winnipegosis generally increase from the north to south end of the lake. Average TDS levels in Dawson Bay (539 mg l^{-1}) are less than those in the basin north of Birch Island (736 mg l^{-1}), which in turn are less than those south of Birch Island (805 mg l^{-1}) (A. Beck, pers. comm.). The Lake Winnipegosis drainage basin lies totally within sedimentary topography, thus accounting for the lake's high TDS levels.

Because of the complex nature of the major lakes and the lack of comprehensive water quality information on all parts of the lakes, the morphoedaphic index did not provide a realistic estimate of the potential fish yields. Since lakes Winnipeg, Winnipegosis and Manitoba have been subjected to moderate or heavy fishing effort over at least the past two decades, it was assumed that a better indicator of sustainable yield potential could be derived from the long term production records.

Lake Winnipeg - Lake Winnipeg has had an annual production of 5.0 million kg between 1950 and 1980. Of this amount, approximately 3.8 million kg yr^{-1} has been accounted for by whitefish, walleye, sauger and pike. Catches from Lake Winnipeg have fluctuated from a high during World War II to a low in 1972, immediately following closure of the fishery due to mercury contamination. Total landings in 1940/41 were 9.9 million kg of which the major species were:

sauger	4.0 million kg
walleye	1.8 million kg
whitefish	1.6 million kg
pike	1.4 million kg
total	8.8 million kg

The remaining 1.1 million kg consisted of less desirable species or species which are not normally exploited; eg. suckers, tullibee, burbot, yellow perch, etc. The Lake Winnipeg stocks apparently were unable to sustain this high level of production. During the mid-1950's and through the 1960's, production levels from Lake Winnipeg declined steadily (Fig. 7). At this time, signs of severe overfishing, at least in some populations such as whitefish and walleye (Fig. 21), were evident. Walleye landings dropped from 3 million kg in 1951 to less than 0.5 million kg yr^{-1} in the late 1960's. Whitefish catches fell from 1.6 million kg in 1950 to about 0.5 million kg yr^{-1} in the late 1960's. The 1950's saw a conversion from cotton to the more efficient nylon gillnets, while during the 1960 decade small mesh (illegal) gillnets were prevalent in the fishery. These factors undoubtedly were important factors contributing to the overfishing of stocks.

More recently, catches from Lake Winnipeg have been on the increase. Since the opening of the fishery after the 1970-71 closure, a "fishing-up" period has occurred. This "fishing-up" process was

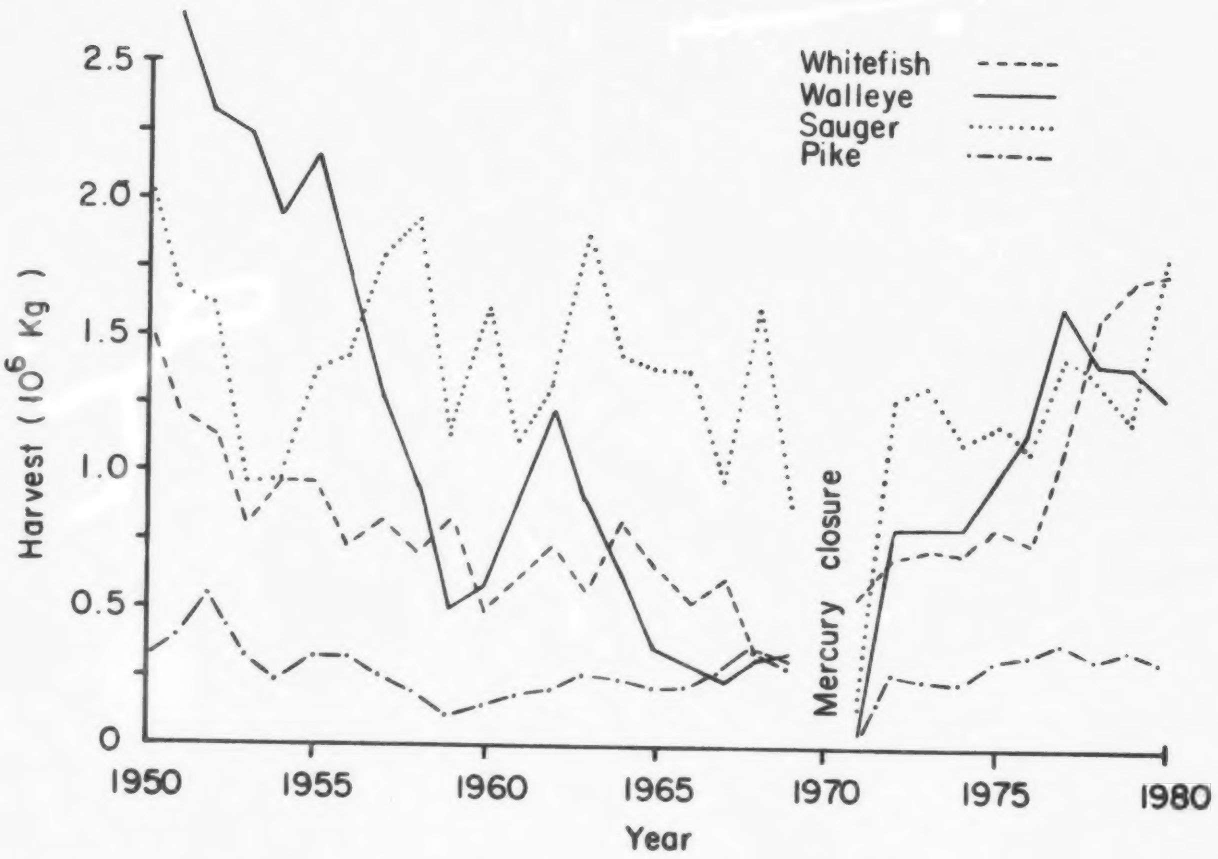

Fig. 21. Landed quantities (kg) of major quota species from the Lake Winnipeg commercial fishery, 1950 - 1980.

controlled by gradual increases in the catch quotas for whitefish, walleye, sauger and pike. Between 1976-1980, the average combined landings of whitefish, walleye, sauger and pike has been about 4.6 million kg yr^{-1}. However, signs of stress are beginning to reappear in the fishery (Lysack 1980).

The maximum sustainable yield of whitefish, walleye, sauger and pike from Lake Winnipeg is probably around 4 million kg yr^{-1}. This yield is approximately one third of the theoretical yield of Lake Winnipeg. Considering Lake Winnipeg as an entity with uniform chemical characteristics, a potential yield of 4.9 kg $ha^{-1}yr^{-1}$ is derived, based upon an MEI of 16.7. This MEI was derived using data from Crowe (1972), Kristofferson et al. (1975) and Brunskill et al. (1980). With the water surface area of Lake Winnipeg being 23,760 km^2, the potential yield is estimated to be 11.6 million kg yr^{-1}. Partitioning this yield for walleye, sauger, pike and whitefish provides a commercial harvest potential of 7.4 to 8.8 million kg yr^{-1}. These values exceed the long term average production of Lake Winnipeg. This emphasizes that caution must be used when attempting to apply to MEI in determining potential yields from large complex systems such as Lake Winnipeg. The estimation of fish yields from Lake Winnipeg based on morphoedaphic characteristics should properly consider the north basin, central area and south basin as separate entities because of their distinct morphometric and limnological characteristics. Consideration of the separate portions of the lake, however, does not provide a complete picture either. It is known that fish stocks in the three areas are not totally discreet. For example, during certain times of the year catches in the south basin may consist of fish originating from the Channel Area. The extent of stock intermingling or fish migrations are not presently well understood.

Lake Winnipegosis - The long term annual harvest from Lake Winnipegosis is 2.1 million kg yr^{-1} (Fig. 7). Lake Winnipegosis fishermen market a large amount of suckers. The 1950-1980 average sucker catch was 1.1 million kg yr^{-1}. Average annual harvests of walleye and pike have been about 1.0 million kg over the 1950-1980 period (Fig. 22). Commercial catches were as high as 1.7 million kg yr^{-1} during the mid-1950's. In recent years (1976-1980) the fishery has, however, only produced combined walleye and pike landings of 0.8 to 1.0 million kg yr^{-1}. The greatest proportion of these catches consisted of pike (Fig. 22). Pike have comprised about 70 per cent of the combined walleye/pike catch since the late 1960's.

In view of the long term average and the recent annual average production from Lake Winnipegosis, the maximum sustainable yield of walleye and pike combined is approximately 1.0 million kg yr^{-1}. Over the 30-year period, 1950-1980, walleye have represented about 38 per cent of this value.

The long term yield from Lake Winnipegosis is only about one half of what the MEI potential yield indicates. The total annual potential harvest was found to be 6.7 million kg yr^{-1} based on an MEI derived yield of 13 kg $ha^{-1}yr^{-1}$ and a water surface area of 5164 km^2. Partitioning this yield to account for the two quota species (pike and walleye) provides a theoretical commercial yield of 2.0 or 2.7 million kg yr^{-1}. Note that two yields are presented;

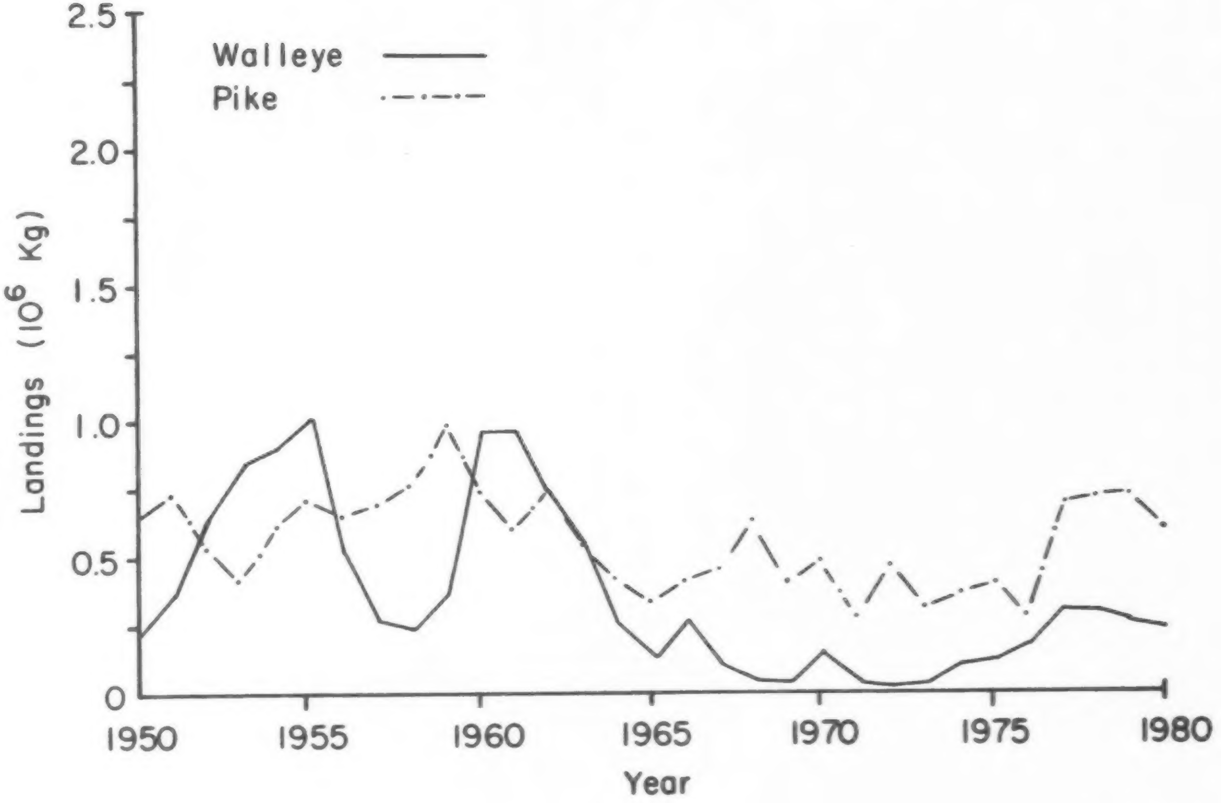

Fig. 22. Landed quantities (kg) of walleye and pike from the Lake Winnipegosis commercial fishery, 1950 - 1980.

this is because 10 and 20 per cent yields of pike were applied to the total potential yield. Extraction of 2 to 3 million kg of pike and walleye each year on a sustained basis would likely result in overfishing. These yields are considered to be overestimates of the potential yield from Lake Winnipegosis. The MEI derived estimates of yields are believed to be erroneous since Lake Winnipegosis is situated in limestone topography and receives significant groundwater inflows. This accounts for its high mean TDS level (719 mg l^{-1}, A. Beck, pers. comm.) and consequently a high MEI and potential yield. The historical production of walleye and pike from Lake Winnipegosis therefore appears to provide a better indicator of sustained productivity.

Lake Manitoba - Average landings of walleye, sauger and pike from Lake Manitoba have been approximately 1.0 million kg yr^{-1} over the 1950-1980 period (Fig. 7). The maximum recorded catch of all species of fish from Lake Manitoba was 4.3 million kg in 1940/41. Walleye, sauger and pike represented 2.8 million kg of this catch. The second highest catches of walleye, sauger and pike occurred during the mid-1950's to mid-1960's (Fig. 23). During this period, landings of these species fluctuated between 1.0 and 1.8 million kg. Recent catches have been lower than the long term average and range from slightly less than 0.5 million kg yr^{-1} to 1.0 million kg yr^{-1} of walleye, sauger and pike.

Judging from the long term production trends, a reasonable sustained yield from Lake Manitoba is approximately 1.0 million kg yr^{-1} for the combined catch of walleye, sauger and pike. Walleyes

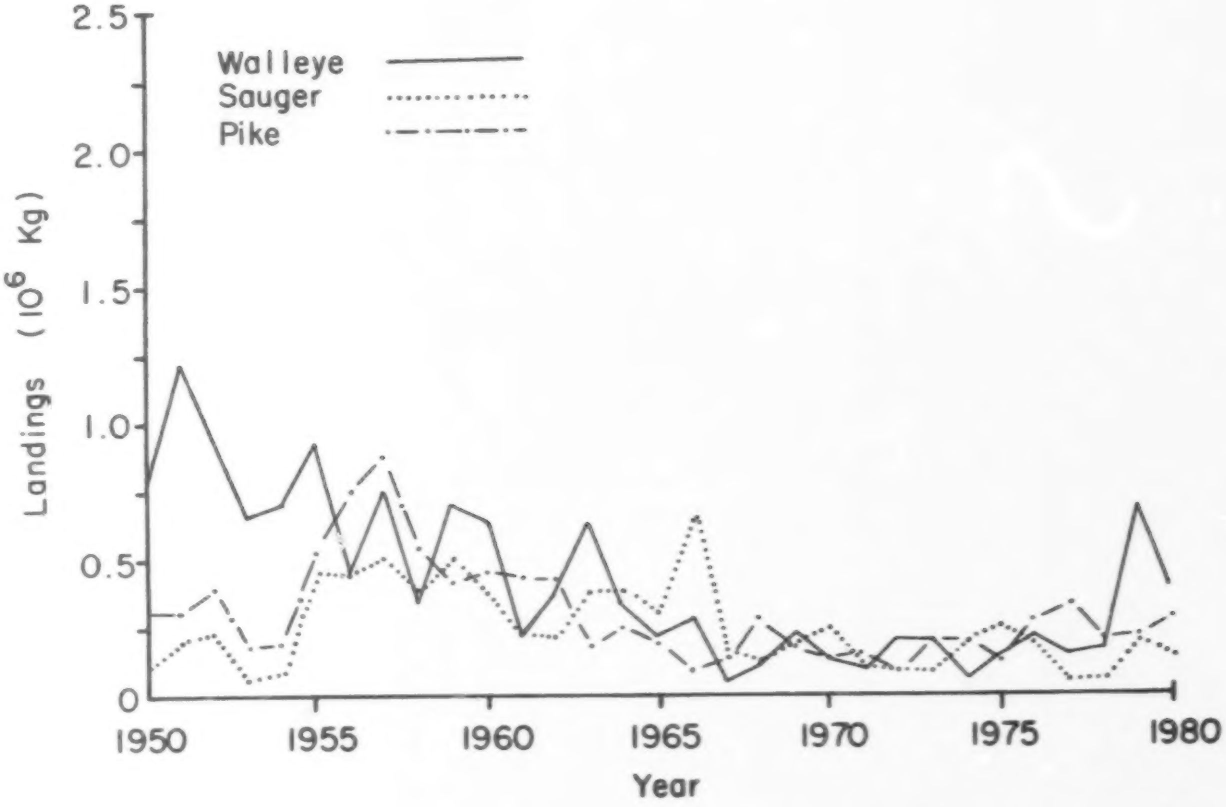

Fig. 23. Landed quantities (kg) of walleye, sauger and pike from the Lake Manitoba commercial fishery, 1950 - 1980.

have generally been the dominant species taken, followed by pike and then sauger. The 30-year average catch indicates that the contributions of walleye, sauger and pike to the catch have been 43, 31 and 26 per cent, respectively.

The theoretical yield for Lake Manitoba, as estimated from the MEI, is an extremely high value. The MEI for Lake Manitoba was 244. It was determined using information from Teller and Last (1980) and A. Beck (pers. comm.). The high index is the result of exceptionally high TDS levels. The average TDS concentration for Lake Manitoba is 1100 mg l^{-1}. Lake Manitoba is also a relatively shallow lake with a mean depth of only 4.5 m. Using the above MEI value, the theoretical yield for Lake Manitoba is 16 kg $ha^{-1}yr^{-1}$ or 7.4 million kg yr^{-1} for an area of 4607 km^2. Partitioning this yield to consider only quota species (walleye, sauger and pike), the potential annual yield is 2.2 or 3.0 million kg. These yields are probably erroneous for the following reasons. Firstly, the MEI for Lake Manitoba is more than twice the optimum of 100 as indicated by Ryder _et al_. (1974). Secondly, the high TDS levels found in Lake Manitoba, especially in the south end, are due mainly to groundwater intrusion. These inflows may increase the TDS by additions of chlorides and sulfates. Cober (1968) observed chloride and sulfate concentrations at some limnological stations in Lake Manitoba to be three times higher than those reported by Bajkov in 1930. Since chlorides and sulfates are not significant factors in primary productivity, they would not contribute to the high fish yields estimated from the MEI.

Summary of maximum potential yields from the major lakes - Combining the maximum sustainable yields as determined from long term production records, the three major lakes in Manitoba could produce a total yield of 6 million kg yr^{-1} of whitefish, walleye, sauger and pike (Table 13). The most important species, in terms of quantities harvested and value to fishermen, is the walleye. It should also be noted that Lake Winnipeg alone can produce more fish than the combined harvests of Lake Winnipegosis and Lake Manitoba. Most of the whitefish, walleye and sauger catches come from Lake Winnipeg, while most of the pike production comes from Lake Winnipegosis and Lake Manitoba. The importance of suckers to the fisheries on the three major lakes is indicated in Table 13. Suckers or mullets have constituted half of the Lake Winnipegosis production and approximately one third of the Lake Manitoba production. Although mullet prices paid to fishermen are extremely low compared to walleye or even pike prices, the incidental capture and opportunity to market them makes fishing more viable for Lake Winnipegosis and Lake Manitoba fishermen.

Summary of Potential Yields from Manitoba Waters

The total potential harvest from Manitoba waters is estimated to be in the order of 17.4 million kg yr^{-1} of whitefish, walleye, sauger and pike (Table 14). This estimate does not include 10.4 million kg of the above species from northern lakes less than 500 ha in size nor any estimate of production from the larger rivers. Fish production potential from rivers in Manitoba are probably minimal except in extensive floodplain areas (eg. the Saskatchewan River and Red River

Table 13. The average annual catches of various fish species from each of the three major Manitoba lakes and the 3 lakes combined over the period 1950 - 1980. Figures in parentheses are percentages of species catch compared to the average total annual catch from the lake, as shown at the bottom of each column.

Species	Average annual catch in kg[1] from -			Total
	L. Winnipeg	L. Winnipegosis	L. Manitoba	(kg)
Whitefish	886,000 (18.3)	27,900 (1.3)	5,400 (0.3)	919,300 (10.3)
Walleye	1,180,100 (24.3)	376,000 (17.9)	434,900 (22.4)	1,991,000 (22.4)
Sauger	1,385,100 (28.5)		259,000 (13.3)	1,644,100 (18.5)
Pike	306,600 (6.3)	576,700 (27.4)	313,700 (16.1)	1,197,000 (13.4)
Tullibee	461,200 (9.5)			461,200 (5.2)
Suckers		1,052,800 (50.0)	626,200 (32.2)	1,679,000 (18.9)
Other[2]	634,300 (13.1)	71,500 (3.4)	305,700 (15.7)	1,011,500 (11.4)
Total	4,853,300	2,104,900	1,944,900	8,903,100

[1] Figures rounded to nearest 100 kg.

[2] May include some quota species listed above, but generally consists of species considered as coarse fish (eg. suckers, tullibee, carp, bullhead, etc.)

Table 14. The estimated total potential harvest[1] (10^6 kg yr^{-1}) of the four prime quota species from Manitoba waters.

Species	Northern lakes	Major lakes	Southern lakes	Total
Whitefish	5.1	0.9	0.8	6.8
Walleye	2.1	2.0	0.9	5.0
Sauger	-	1.6	-	1.6
Pike	1.6	1.2	1.2	4.0
Total	8.8	5.7	2.9	17.4

[1] Total potential harvests for Northern and Southern lakes are the total partitioned potential yields.

Table 15. Estimated potential fish production for non-quota large fish species in Manitoba waters and percentage of non-quota species caught from experimental netting in relation to the numbers of the preferred species.

Area	Estimated potential (millions of kg)	Percentage of non-quota species
Lake Winnipeg	4.3	52
Lake Winnipegosis	1.1	53
Lake Manitoba	0.96	49
Northern	10.3	54
Southern	2.1	42*
Total	18.8	

* Percentage of non-quota species by weight from experimental gillnets.

deltas) This does not imply, however, that rivers are not important fish habitat. Rivers frequently constitute major spawning and feeding areas for many lake dwelling fish populations.

The totals presented in Table 14 must be considered as orders of magnitude rather than precise amounts. They must also be interpreted with considerable care. Because of the nature of existing exploitation patterns and the allocation of fish resources, some of the potential may not be realized. For example, the potential yield of whitefish from southern lakes applies primarily to the larger lakes in the central and southeastern portions of the Province. Whitefish populations in southeastern lakes may not be fully exploited since these waters are reserved solely for sport fishing and anglers do not as a rule seek out whitefish. Unless exploitation is highly selective, the use of more efficient gear to produce higher yields of one species may result in overexploitation and the decline of other co-habiting populations. Much of this dilemma applies to the exploitation of walleye and sauger. The simultaneous exploitation of both species can be difficult without causing some detrimental effects (Schlick 1978). These effects are generally observed in the walleye stocks. Since adult sauger are generally much smaller than walleye, small mesh gillnets are required to fully exploit sauger. The use of small mesh nets can result in harvesting immature walleye and consequential declines in their reproductive success.

The foregoing discussions have not included any reference to lake sturgeon (Acipenser fluvescens). This species is a highly desirable, commercial fish and at one time was produced in significant quantities from Manitoba water (Harkness 1980). Currently, commercial sturgeon fisheries, which are limited by catch quotas, are permitted on the Nelson River, the Hayes-Gods River, and the upper portion of the Churchill River. Occasionally, incidental catches of large sturgeon are made in other northern lakes and on the major lakes, particularly Lake Winnipeg. Total production of sturgeon is generally low; recent figures indicate a total Manitoba catch of less than 10,000 kg. Because of the small production, sturgeon were not considered in potential yield estimates.

Other Large Fish or Non-quota Species

Species of fish other than the preferred species (i.e whitefish, walleye, sauger, pike and lake trout) have been neglected in discussions to this point because these species of fish are not usually sought after by fishermen. Their capture is normally incidental to that of the preferred species. Some of these "other or non-quota" species which do demand high market values at times are yellow perch (*Perca flavescens*), mooneye (*Hiodon tergisus*) and goldeye (*Hiodon alosoides*). Catches of these species are generally small compared to the preferred species and therefore their importance to the fishery is limited. Additional large fish species captured in Manitoba waters have commonly been referred to as "rough or coarse fish" because of their low market demand and value. Moshenko (1975) listed the following species which are considered as rough fish:

White sucker - Catostomus commersonii

Longnose sucker - Catostomus catostomus

Redhorse sucker - Moxostoma spp.

Quillback sucker Carpiodes cyprinus

Burbot - Lota lota

Tullibee - Coregonus spp.

Carp - Cyprinus carpio

Freshwater drum - Aplodinotus grunniens

Channel catfish Ictalurus punctatus

Bullheads - Ictalurus spp.

The term "non-quota species" where used in this report applies to the above listed species as well as to others such as yellow perch, mooneye, goldeye, white bass, etc. Although whitefish and pike catches are normally regulated by quotas, on some lakes they are not. For example, quotas are not established for whitefish which are highly infested with the parasite, Triaenophorus. Also, pike catches on Lake Winnipeg are unrestricted. In this report, however, pike and whitefish are considered as preferred species.

A crude estimate of the potential production of non-quota fish from Manitoba waters is approximately 19 million kg yr^{-1} (Table 15). This estimate excludes any possible production from northern lakes less than 500 ha in size. The percentage composition of non-quota species versus preferred species derived from experimental gillnetting results was used to estimate the potential production of non-quota species (Appendix IX). The ratios of non-quota to preferred species were applied to the theoretical yield of the preferred species to estimate the theoretical yield of non-quota species. Based on experimental netting on Lake Winnipeg, non-quota species in terms of numbers represented 52 per cent of the catches. Since the theoretical yield of preferred species from Lake Winnipeg was 4.0 million kg yr^{-1}, it is therefore estimated that the potential yield of non-quota species would be 4.3 million kg yr^{-1}.

The above method represents a rather crude approach since the extrapolations are based on numbers of fish. One deficiency in this approach is that not all fish species have equivalent sizes. The sizes of walleye or pike represented in experimental gillnet catches are normally greater than those of yellow perch or tullibees. Consequently, the biomass of non-quota species may be overestimated. This situation may be particularly true for southern Manitoba lakes. Non-quota species from southern lakes represented 66 per cent of the experimental catches by number, but only 42 per cent of the catches by weight. This variation showed the potential yield of non-quota species, when based on numbers, was twice as large as the yield estimate based on weights. The estimated potential for non-quota species from southern lakes using weights of fish was 2.1 million kg, while numbers produced an estimate of 5.6 million kg. Because of the magnitude of this variation from southern lakes, biomass estimates of non-quota species were based upon species composition by weight.

Species compositions based on numbers of fish were used for all other regions since most of the information was only obtainable in that form. However, available information indicated that species compositions of experimental catches were similar when either numbers or weights were considered. Much of this information was for northern lakes. The ratios between preferred and non-quota species were only about three per cent greater when weights were considered. Similar conditions are thought to pertain to the three major lakes. Data on weights of fish caught by experimental gillnetting were not available for the major lakes. However, non-quota species generally caught from these waters are comparable in size to the preferred or quota species. One exception to this generalization applies to Lake Winnipeg where large numbers of tullibees are caught in experimental nets. Because of this, non-quota species may appear to represent a much higher proportion of the total potential yield from Lake Winnipeg when the estimate is based upon numbers. The yield estimate for non-quota species using numbers appears to be approximately 10 per cent higher than an estimate based on weight.

The average annual landings of non-quota species from Manitoba waters over the period 1950-1980 has been around 3.5 million kg. Quantities of non-quota fish species marketed in more recent years have been similar to the long term average. The 1975-1980 average was 3.2 million kg yr^{-1}. These values are much less than the estimated potential yields. However, it should be recognized that the landings do not accurately reflect the actual quantities that are harvested by fishermen. Because of low market demands for most of the non-quota species and poor returns to the fishermen, much of the catch of non-quota species is discarded and does not appear in the commercial catch records. Moshenko (1975) estimated that about 11 million kg of rough fish were taken from Manitoba waters in 1974/75. This is approximately 60 per cent of the estimated potential (18.8 million kg) or three times as much as the recorded average annual landings.

PART V

PROJECTED FUTURE DEMANDS

As previously indicated, there are six categories of comsumptive demands on Manitoba's fish resource which can be readily identified. They are:

commercial fishing
sport fishing
domestic (subsistence) fishing
bait fishing
scientific collecting
aquaculture

The latter three groups at the present time seem to have a minor impact on stock abundance of the larger fish species. Bait fishing involves the removal of small fish species or minnows for commercial sale to sport fishermen. An estimated 27,000 kg of bait fish were harvested annually from Manitoba between 1974-1976. The impact of this harvest on small fish stocks is unknown. Lack of adequate data on bait fish populations and exploitation prevents the derivation of any estimate of a maximum sustainable yield. Proper scientific management of the bait fish industry is important since minnows and other small fishes are a significant link in the food chain of the larger, exploited fish species. Scientific collection of fish is restricted to educational institutions, generally universities, and to government agencies engaged in fisheries research or management.

Aquaculture in Manitoba, as previously mentioned, is restricted at the present time to a "put and take" rainbow trout fishery. Fish hatcheries owned and operated by the provincial government also use spawning walleyes and whitefish as a source of fertilized eggs, but the adults are returned to their natural environment once the spawn has been collected. The hatchery-produced fry are used to re-establish, maintain or supplement walleye or whitefish populations in various parts of the Province. Aquaculture activities may also involve purchasing adult pike from commercial fishermen fishing for suckers on their spring spawning run. These pike are then transferred to winterkill lakes in southwestern Manitoba to provide further angling opportunities. Both scientific collecting of fish and aquaculture are considered as having minimal impacts of the abundance of natural fish stocks.

At present, commercial, sport and domestic fishing exert the most significant demands on the fish resource. These demands are greatest on walleye, whitefish and northern pike stocks and have considerable economic implications.

Domestic Fishing

Domestic fishing is the harvest of fish by people for their own consumption or for animal consumption; i.e. sled dogs. Fishing for dog food has decreased since the advent of snowmobiles. Domestic fishing occurs mainly in the remote northern communities. The domestic consumption of fish in Manitoba was estimated to be approximately 1.2

million kg in 1975 and it is projected to increase to about 3.4 million kg by the year 2000 (Table 16). These estimates were based on a per capita consumption of 35 kg yr^{-1} and existing and projected population figures for native northern communities.

The 35 kg figure was derived from several independant surveys of domestic fishing in different remote northern communities (Appendix X). Weagle (1973) determined that the domestic consumption of fish by Norway House residents was about 48,000 kg or 28 kg per capita. Adams et al. (1976) estimated that the per capita consumption of locally caught fish at several northern communities ranged from 12 to 38 kg. The most in-depth survey on domestic fishing was conducted in the community of Cross Lake in 1980 and 1981. It revealed an annual per capita consumption of 46 kg (Gaboury and Patalas 1982). Gaboury and Patalas (1982) indicated that actual consumption may have been underestimated by as much as 20 per cent since some fishermen were reluctant to participate in the survey and individuals who fished infrequently were excluded. Gaboury and Patalas (1982) also found that whitefish, walleye and pike formed 54 per cent of the catches by domestic fishermen. Based on this information, domestic fishermen could harvest between 1.8 and 2.4 million kg of whitefish, pike and walleye in the year 2000 (Table 16).

Projected populations in native communities were determined from previous population growth trends between 1971-1980. The population in native communities increased by approximately four per cent per annum, based on statistics from the Manitoba Health Services Commission. Providing that rate of population increase holds until

Table 16. Estimated and projected domestic consumption of fish (10^6 kg yr^{-1}) from Manitoba, 1975 - 2000.

Year	Native community population		Consumption							
			35 kg. per capita				46 kg. per capita			
	All communities	Northern only	All communities		Northern only		All communities		Northern only	
			All species	Whitefish, walleye & pike*	All species	Whitefish, walleye & pike*	All species	Whitefish, walleye & pike*	All species	Whitefish, walleye & pike*
1975	35,000	31,500	1.2	0.65	1.1	0.59	1.6	0.86	1.5	0.81
1980	44,000	39,600	1.5	0.81	1.4	0.76	2.0	1.1	1.8	0.97
1985	54,000	48,600	1.9	1.0	1.7	0.92	2.5	1.4	2.2	1.2
1990	65,000	58,500	2.3	1.2	2.1	1.1	3.0	1.6	2.7	1.5
1995	80,000	72,000	2.8	1.5	2.5	1.4	3.7	2.0	3.3	1.8
2000	97,000	87,300	3.4	1.8	3.1	1.7	4.5	2.4	4.0	2.2

* Whitefish, walleye and pike represented 54% of domestic catches from Cross Lake (Gaboury and Patalas, 1982).

[1] Northern communities included those native reserve communities minus the southern communities. These southern communities were Oak Lake, Rolling River, Gambles, Waywayseecappo, Valley River, Birdtail Scoux, Keeseekowenin, Swan Lake, Long Plain and Roseau River.

2000, the total population of all native communities would increase to approximately 97,000 (Table 16). This estimate seems reasonable since the projected population for 1990, calculated using a four per cent rate of increase, is similar to the 1990 estimate made by Maki et al. (1973). Maki et al. (1973) projected population figures using various models. The model which produced the greatest population growth provided an estimate that was slightly lower than the actual population listed for 1975 and 1980. Likewise, their projection of the native population in 1990 is slightly lower than that reported in Table 16.

Population figures reported in Table 16 also include native communities from southern Manitoba. Some of these communities are not situated near large lakes and, therefore, domestic consumption of fish in these communities is believed to be minimal. The total consumption, as presented in Table 16, would be reduced by about 10 per cent if the southern native communities are not considered. The population of these communities (i.e Oak Lake, Rolling River, Gambles, Waywayseecappo, Valley River, Birdtail Sioux, Keeseekoowenin, Swan Lake, Long Plain and Roseau River) represents approximately 10 per cent of the total Manitoba native population.

The impact of domestic fishing of fish stocks at the present time appears to be marginal. Domestic harvests of whitefish, walleye and pike are estimated to be 5-6 per cent of the estimated available potential (17.4 million kg). The estimate of domestic harvests assumes a per capita consumption of 35 to 46 kg. Assuming an equivalent range in per capita consumption prevails, larger overall harvests can be expected with a continually growing population. If the reported population trends persist to the year 2000, domestic harvests may reach 10 to 14 per cent of the estimated available potential of whitefish, walleye and pike stocks. Exclusion of the southern native communities only reduces the future demand by about 1.0 per cent.

Sport Fishing

According to recent surveys, the estimated harvests of sport fish have increased from about 3.6 million kg in 1975 to 4.0 million kg in 1980. The 1980 sport fishing survey indicates that walleye and pike comprise 94 per cent of the primary species (i.e. walleye, pike, lake trout, rainbow trout, brook trout and smallmouth bass) which are kept by anglers. This represents approximately 22 per cent of the estimated potential yield of the prime fish species, (i.e 17.4 million kg of whitefish, walleye and northern pike). If past trends in the growth of sport fishing popularity prevail, projected demands indicate that the total sport fish harvests will be substantially higher by year 2000.

Estimates of sport fish harvests were mainly derived using information from the 1975 and 1980 sport fishing surveys, various creel census reports and the records of annual angling licence sales. The mean weight of the main fish species caught by sport fishermen, as indicated by the 1980 survey, was approximately 1.0 kg per fish. The 1975 and 1980 survey indicated that the average number of the main species kept annually per angler was 20 fish. Estimates of present and future fish production were then the result of the product between the average weight of the main species retained by anglers and the number of anglers in Manitoba. Angling licence sales were used to indicate the angler number, although it should be noted that residents of Canada under age 16 or over 65 do not require a licence to angle in Manitoba. A 1981 survey by provincial conservation officers and park rangers found that in 30,500 anglers polled, 29 per cent were from the under 16 and over 65 age groups. This means that in a year such as 1980, there would have been an additional 58,000 unlicenced resident anglers in the above age groups.

Past trends and future estimates of sport fishing licence sales were described by regression analysis. The two mathematical functions which best illustrated past trends were the linear and exponential regressions. These regressions were applied to data records for licence sales from 1955 to 1980. Information prior to 1955 was excluded since resident anglers only required fishing permits for the winter season.

The two main angler groups defined in sport fishing regulations are resident and non-resident anglers. Resident anglers are persons who have resided permanently in Canada for a period of at least one month or are Canadian military personnel. Any residents of Canada living in other provinces or territories are therefore considered as resident anglers. Non-resident anglers refer to those who reside outside of Canada. Virtually all of the non-residents anglers who fish in Manitoba are Americans. The largest proportion of Americans who fish in Manitoba come from the neighboring states of Minnesota and North Dakota.

Resident anglers

Resident angler licence sales increased from 56, 595 in

1955 to 159, 584 in 1980 (Fig. 24, Appendix XI). This represents an annual average increase of 4.2 per cent in licence sales. This long term increase is similar to the rate of increase in licence sales over the period 1971-1980. The annual rate of increase in that decade was 4.4 per cent. A continuing increase at this rate would result in the sale of about 360,400 resident angling licences by 2000.

Regression analysis of angling licence sales showed similar correlation coefficients for both the linear and exponential regression functions. The correlation coefficients (r) for the linear and exponential regressions were 0.941 and 0.945, respectively. Such high coefficients show good fit to the data and indicate good predictability by both regressions. However, the projections based upon the two types of regressions are seen to vary considerably (Fig. 24, Table 17). By 2000, total resident licence sales as predicted from the linear and exponential regressions are 231,000 and 331,500, respectively. As indicated in Table 17, projected estimates from the linear regression are as much as 30 per cent lower than those derived from the exponential regression for the year 2000. The two regressions probably provide a good estimate of the minimum and maximum range in future angling licence sales. However, since sport fishing seems to be gaining in popularity, the exponential regressionn may be a better indicator of the future trend in the growth of the angler population.

Reasons for assuming that future angling licence sales may be best represented by an exponential regression have been based on past events. For the most part, the prediction of future events is based on past trends and the assumption these same trends will

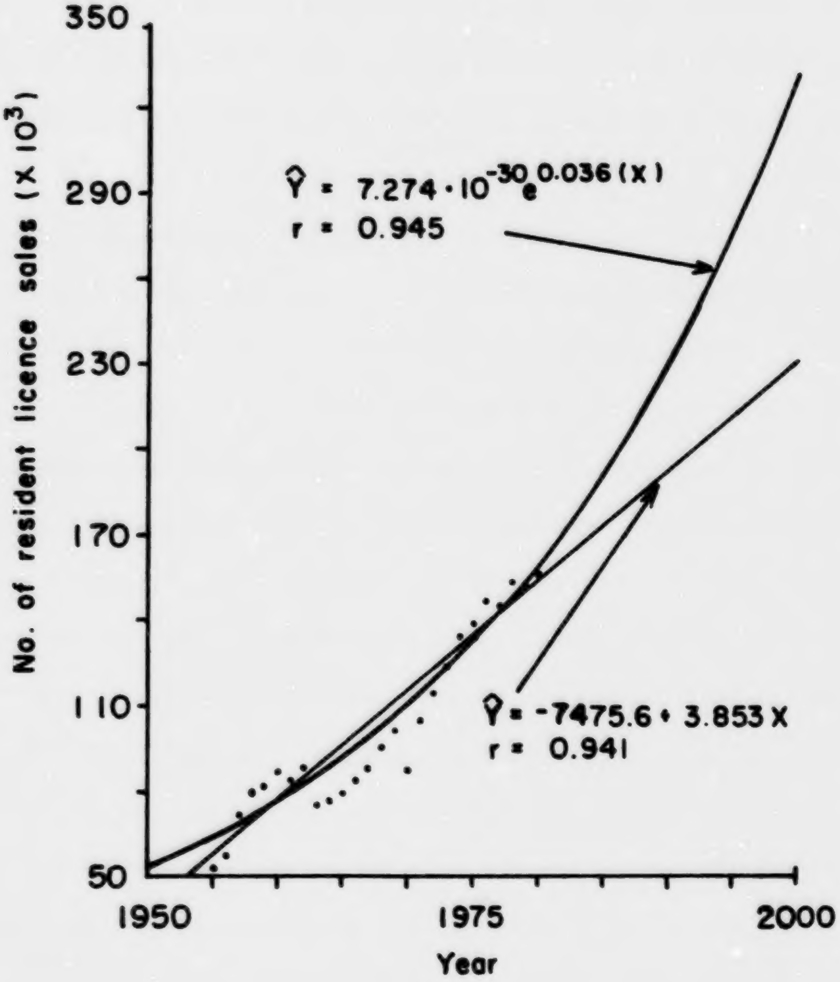

Fig. 24. Linear and exponential regressions of resident angling licence sales, 1955 - 1980. Regression lines indicate licence sales projections to year 2000.

Table 17. Projected estimates[1] of resident sport angling licences sales, unlicensed anglers (anglers less than 16 and over 65 years of age) and associated harvests of fish (10^6 kg) by these angler groups up to year 2000.

Year	Licenced anglers				Unlicenced anglers[2]				Total			
	Linear regression		Exponential regression		linear reg.		exponential reg.		linear reg.		exponential reg.	
	licences sold	catch (kg)	licences sold	catch (kg)	no.	catch (kg)	no.	catch (kg)	no.	catch (kg)	no.	catch (kg)
1975	142,200	2.84	142,200	2.84	35,900	0.72	35,900	0.72	178,100	3.56	178,100	3.56
1980	159,600	3.19	159,600	3.19	40,300	0.81	40,300	0.81	199,900	4.00	199,900	4.00
1985	173,200	3.46	191,900	3.84	43,700	0.87	48,400	0.97	216,900	4.33	240,300	4.81
1990	192,400	3.85	230,200	4.60	48,500	0.97	58,000	1.16	240,900	4.82	288,200	5.76
1995	211,700	4.23	276,300	5.53	53,400	1.07	69,700	1.39	265,100	5.30	346,000	6.92
2000	231,000	4.62	331,500	6.63	58,300	1.17	83,600	1.67	289,300	5.79	415,100	8.30

[1] Number of licences rounded off to nearest hundred.

[2] Number of unlicenced anglers considered to be equal to 29 percent of the licenced number - from conservation officer and park ranger surveys conducted in 1981.

continue to exist over the next couple of decades. The higher correlation coefficient for the exponential regression suggests that the past growth in licence sales was more exponential than linear. As previously mentioned, the long term growth trend showed licence sales were increasing by a little over 4.0 per cent per year. Continued growth at this rate indicates that resident licence sales would actually be 9.0 per cent higher in the year 2000 than the estimate derived from the exponential regression.

Some consideration was given to the possibility that the rate of angling licence sales may decrease because the growth rate of Manitoba's population has been decreasing since the 1950's. Contrary to this decrease in population growth, there appears to be an increase in the rate of growth in angling licence sales. Resident angling licence sales do not appear linked to the rate of population growth. The number of resident licences purchased has grown from 7.2 per cent of the provincial population in 1956 to 15.6 per cent of the population in 1980. Larger proportions of the population which buy angling licences have been attributed to a previous assumption that the amount of disposable income among the general population has increased in recent years. There has also been a significant increase in popularity of sport fishing.

Although there is no consistent relationship between the number of angling licences sold and the population, such comparisons aid in further evaluating the outcome of projected estimates derived from the regression analysis. The proportion of licenced resident anglers relative to the provincial population increased by 8.4 per cent between 1955 and 1980. This represents an average annual increment of 0.34 per cent. A continued increase at this rate means that licenced resident anglers would form 22 per cent of Manitoba's population by year 2000. Over the past decade (1971-1981) the annual rate of growth has been more rapid. The average yearly increment from 1971-1981 was 0.46 per cent. This means that licenced resident anglers would form about 25 per cent of the provincial population by year 2000. These percentages seem credible as some other Canadian provinces and states in the U.S. already have as much as 20-25 per cent of their populations purchasing angling licences.

Based on the 22 and 25 per cent figures, the number of resident anglers licenced in Manitoba by year 2000 could be anywhere from 273,000 to 310,000. These figures are determined using an estimated population of 1,239,000 for Manitoba in year 2000. This estimate was the largest value of a 1979 population projection made by Statistics Canada (1979). It represents a population growth rate of slightly less than one per cent per year between the years 1978-2000. The smallest population figure projected for Manitoba for the year 2000 was 1,092,000. This represents a growth rate of only 0.3 per cent per year since 1978. The average rate of Manitoba's population increase has been dropping since the 1950's. The annual rate of increase dropped from 1.8 per cent between 1951-1961 to 0.4 per cent between 1971-1981. The number of resident anglers would be approximately 273,000 by the year 2000 if 25 per cent of the projected provincial population (1,092,100) purchased licences. This estimate falls between the estimates obtained by regression analyses.

If it is assumed that there is no future increase in the amount of fish creeled by individual anglers, and if harvest values as determined in the 1980 angler survey are used, the estimated harvest by licenced anglers could range from 4.62 to 6.63 million kg by the turn of the century (Table 17). If unlicenced anglers (i.e. those less than 16 or greater than 65 years of age) are included, the total harvest by resident Manitoba anglers by 2000 could be as high as 8.3 million kg. The amount of fish caught and retained by unlicenced anglers was assumed to be the same as that for licenced anglers determined in the 1980 survey. The estimated harvest by unlicenced anglers may be overestimated, however, since approximately 57 per cent of this group are in the less than 16 age category. Presumably the younger age groups spend less time fishing and catch fewer fish than the older individuals.

Non-resident anglers

Non-resident angler licence sales have increased from 10,072 licences in 1955 to 40,111 in 1980 (Fig. 25, Appendix XI). This represents an average annual increase of approximately 5.8 per cent. Non-resident licence sales have increased at a slower rate between 1971-1980; the average annual increase for this period was only 3.5 per cent. Estimation of future non-resident licence sales employing these rates results in a wide range of estimates. Using a 5.8 per cent increase since 1980 would mean a non-resident angler population

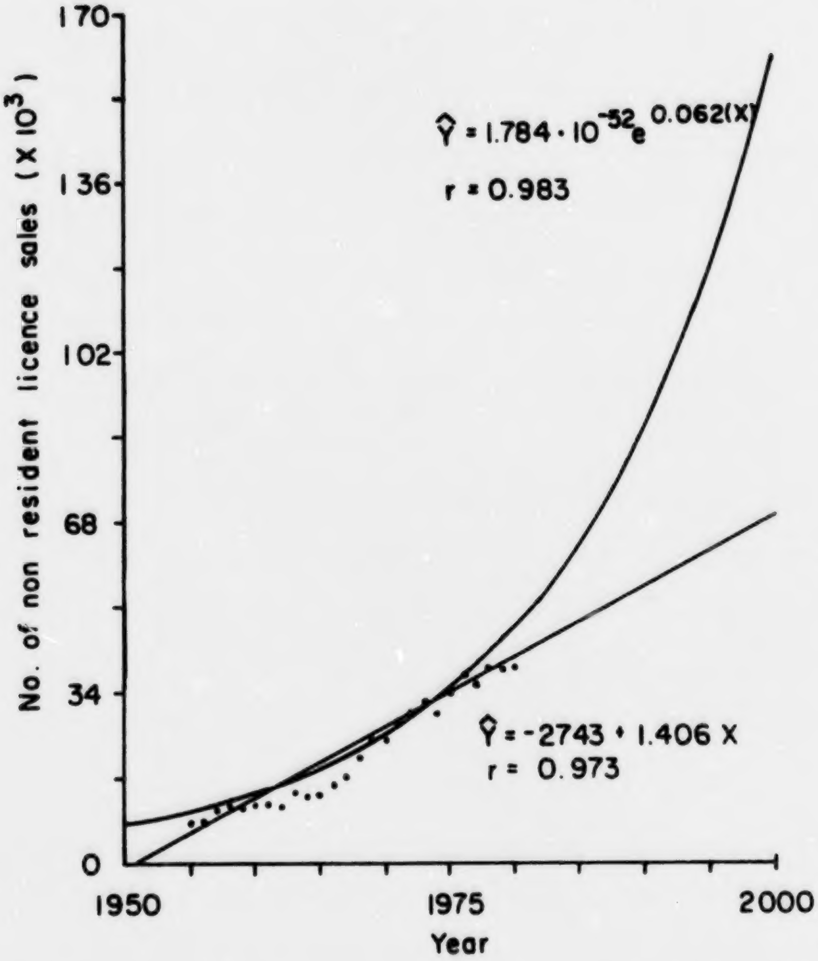

Fig. 25. Linear and exponential regression of non-resident angling licence sales, 1955 - 1980. Regression lines indicate predicted sales to year 2000.

of 127,000 in 2000. With a 3.5 per cent annual increase, the estimate is only 81,600.

Regression analyses of past records of non-resident licence sales also provided a wide range of estimates (Fig. 25). Licence sales estimates in 2000 derived from the linear and exponential regressions are 69,000 and 161,000, respectively (Table 18). The exponential regression equation provided a slightly higher correlation coefficient ($r = 0.983$) than that ($r = 0.973$) of linear regression analysis. Since the exponential regression equation provided the best fit for both the non-resident and resident licence sales, it might be assumed that the same factors affected both angler groups. One factor, previously suggested as a cause for this type of exponential growth, is the growth in disposable income available to the general populace. Although an exponential function best described the growth in non-resident angler licence sales, continued exponential growth to the same degree may be too great to describe non-resident licence sales over the next two decades.

There are two principal reasons for questioning whether the exponential growth in non-resident angler licence sales prior to 1980 will continue at the same rate over the period 1980-2000. Firstly, non-resident licence sales are estimated to be 161,100 by 2000. This level could only be achieved with an annual rate of increase of 7.1 per cent between 1980 and 2000. This increase is not much more than 1.0 per cent yr^{-1} higher than the long term average of 5.8 per cent yr^{-1}. However, non-resident licence sales over the past decade

Table 18. **Projected estimates of non-resident sport angling licence sales and associated harvests of fish (million of kg) by this angler group up to year 2000.**

Year	Linear regression		Exponential regression	
	no.*	catch** (kg)	no.*	catch** (kg)
1975	35,900	0.72	35,900	0.72
1980	41,000	0.82	41,000	0.82
1985	48,500	0.97	63,500	1.27
1990	55,500	1.11	86,600	1.73
1995	62,500	1.25	118,100	2.36
2000	69,600	1.39	161,100	3.22

* Numbers rounded to nearest 100.

** Harvest of fish estimated to be 20 fish per angler and 1.0 kg per fish as calculated from 1975 and 1980 surveys.

have as indicated earlier, been increasing at a much lower rate. The rate of increase between 1971 and 1980 averaged 3.5 per cent yr^{-1}, which is only half the 7.1 per cent rate. The second reason is that the previous relationship between the number of non-resident and resident anglers would have to double by the year 2000 in order to reach the number of non-resident anglers predicted by the exponential regression analysis. This would essentially mean that the ratio of non-resident to resident licences would have to increase from 26 per cent to 49 per cent. Between 1955-1968, non-resident licence sales equalled approximately 18 per cent (range 15-23%) of resident licence sales. In most years, non-resident sales were generally 15-19 per cent of resident licence sales (Appendix XI). Since 1969, this ratio has been even more consistent. Non-resident licence sales have varied between 25 and 27 per cent of resident licence sales (Appendix XI). If a ratio of 26 per cent prevails and provided resident licence sales equal 331,500, non-resident angler licence sales by year 2000 should be in the order of 86,200. This estimate is considerably less than the 161,100 predicted by the exponential regression analysis.

The increase in the ratio of non-resident to resident licences was 8.0 per cent during the periods 1955-1968 and 1969-1980. An 8.0 per cent increase in each of the next two decades would mean non-resident licence sales would equal 42 per cent of the resident licence sales by year 2000. This indicates the total number of non-resident licence sales would be about 139,200 in 2000 or about 23,000 less than the exponential regression estimate. However, it is unlikely such increases in non-resident licences will occur over the next 20 years. The 8.0 per cent increase which occurred in the 1960's and 1970's appears to have been due mainly to the introduction of the 3-day fishing permit, which was first made available to non-residents in 1969. The cost of this permit was half the cost of a seasonal licence. This permit may have encouraged some non-resident anglers, who might not have normally purchased a seasonal licence to fish for several days, to buy an angling licence. These 3-day permits constitute about 30 per cent of the non-resident angler licence sales (Appendix XI).

The 1980 angler survey estimated that the harvest of fish by non-resident anglers was approximately 0.82 million kg. Harvests of fish by non-resident anglers in the year 2000 are estimated to be in the range of 1.4 to 3.2 million kg (Table 18). These harvest estimates have been based on projected licence sales determined from linear and exponential regression analyses and angler harvest rates derived from the 1980 survey.

Total angling licence sales

Total (resident and non-resident) angling licence sales have grown from 67,031 in 1955 to 200,595 in 1980 (Fig. 26, Appendix XI). This increase represents an annual average growth in sales of about 4.5 per cent. Total sales between 1971-1980 have increased approximately 4.2 per cent per year. A continued increase at this rate indicates total angling licence sales will be between 456,000 and 485,000 by the turn of the century. Over the last 12 years (1969-1980), resident licence sales have comprised about 79 per cent of the total sales

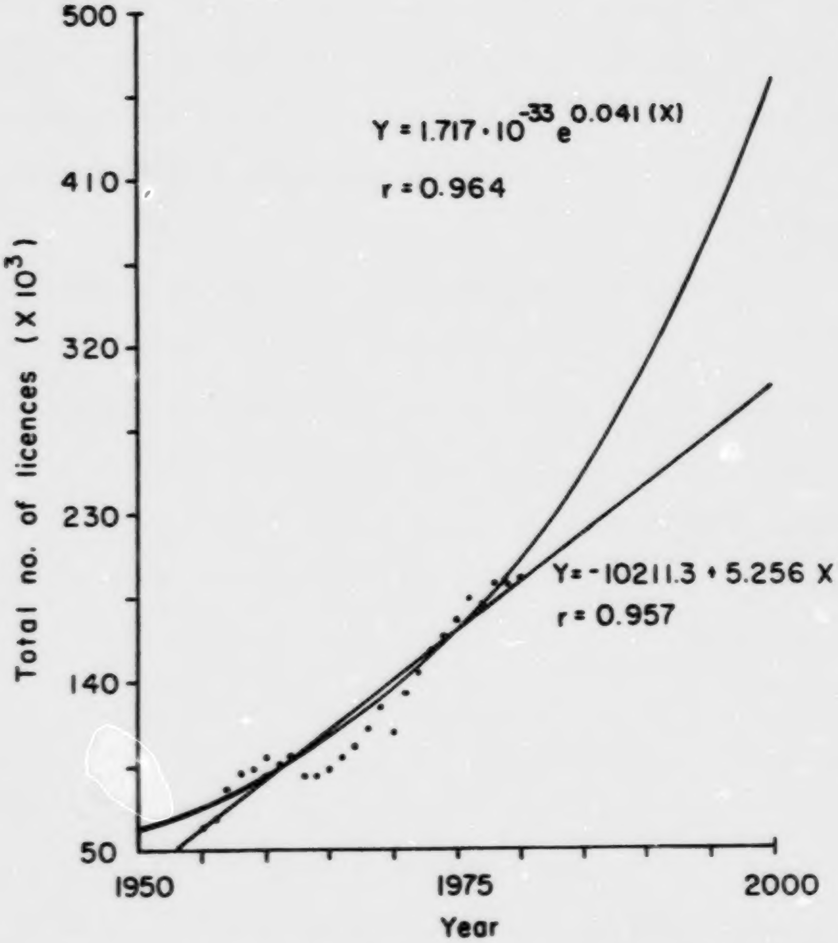

Fig. 26. Linear and exponential regression of total angling licence sales, 1955 - 1980. Regression lines indicate predicted sales to year 2000.

(Appendix XI).

The exponential regression equation provided the best fit to the total angling licence sales. Correlation coefficients for the linear and exponential regressions were 0.957 and 0.964, respectively. Estimates of total angling licence sales from the linear and exponential regressions for the year 2000 were 300,300 and 463,800, respectively (Table 19). The exponential regression appears to provide the best estimate of future total licence sales. The exponentially derived estimate was between estimates derived from projections using a 4.2 and 4.5 per cent annual increase in total licence sales. However, as previously discussed, the future exponential growth in licence sales may be at a slower rate than was experienced in the past.

Although there is a considerable difference in estimates derived from the linear and exponential regressions, the estimates appear to provide a good range within which future licence sales may fall. These projections give some insight into what may be expected over the long term. It must be recognized, however, that future events may not necessarily follow past trends. For example, it has been observed that each time there is an increase in angling licence fees, there has been a slight drop in licence sales. Economic conditions in the future may therefore have an observable effect on angling activity. Because of this, revisions should be periodically made as more data becomes available to re-assess the status of the angling population.

The estimated harvest of fish in the year 2000 by the total number of licenced anglers ranges from 6.0 to 9.3 million kg (Table 19). Harvests by 1985 are projected to be approximately 4.4 to 5.0

Table 19. Projected sport fishing licence sales and estimated angler harvest (10^6kg) of sport fish[1] species from Manitoba waters, 1975 - 2000.

Year	Resident and Non-resident licenced anglers				Unlicenced resident anglers[2]				Total				Species comp.	
	Linear regression		Exponential regression		Linear regression		Exponential regression		Linear regression		Exponential regression			
	no.	est. harvest	no.	est. harvest	no.	est. harvest	no.	est. harvest	no.	est. harvest	no.	est. harvest	species	%
1975	178,000	3.56	178,000	3.56	35,900	0.72	35,900	0.72	213,900	4.28	213,900	4.28	walleye	56
1980	201,000	4.02	201,000	4.02	40,300	0.81	40,300	0.81	241,300	4.83	241,300	4.83	N. pike	38
1985	221,500	4.43	251,500	5.03	43,700	0.87	48,400	0.97	265,200	5.30	299,900	6.00	L. trout	3
1990	247,800	4.96	308,400	6.17	48,500	0.97	58,000	1.16	296,300	5.93	366,400	7.33	R. trout	1
1995	274,000	5.48	378,200	7.56	53,400	1.07	69,700	1.39	327,400	6.55	447,900	8.95	B. trout	1
2000	300,300	6.01	463,800	9.28	58,300	1.17	83,600	1.67	358,600	7.18	547,400	10.95	Sm. bass	1
													Total	100

[1] Main sport fish species included walleye, northern pike, lake trout, rainbow trout, brook trout and smallmouth bass.

[2] Unlicenced resident anglers are those residents <16 and over 65 years of age who don't require a permit to angle.

N.B. Licence sales estimates rounded to nearest 100.

N.B. Number of fish kept per angler was 20 and mean weight of fish kept per angler was 1.0 kg as calculated from the 1975 and 1980 sport fishing surveys.

million kg . Including the harvest of unlicenced anglers, the total estimated annual harvests of sport fish may range from 7.2 to 11.0 million kg by the year 2000 (Table 19). Sport fish harvests of this magnitude are between 2 and 3 times higher than what was estimated to have been harvested by anglers in 1980. Even though angling licence sales may reach or surpass our estimates, the corresponding estimated catches, as shown in Table 19, may not. Increased demands by anglers and other user groups on specific fish stocks may reduce the angler's catch per unit effort in the future. Unless the effort expended by anglers increased to maintain the limit (20 fish kept per angler) estimated from the 1975 and 1980 angler surveys, the total quantities of fish harvested by anglers may be less than anticipated. Future sport fish harvests will also be significantly effected by changing sport fishing regulations.

Supplies of fish under natural conditions will not substantially increase and may in fact decrease because of adverse environmental impacts and habitat loss due to man-made causes. Many southern lakes and streams have already been degraded to the point where fish producing habitat has been lost or where the more desirable fish stocks have been replaced by rough fish populations. Whether changes have been due to environmental degradation or overexploitation, several southern lakes now require frequent restocking of game fish in order to maintain a fishery. The anticipated growth in the angler population will only mean increased fishing effort on such waters and consequently much fewer fish per angler. In order to maintain angler success at the 1980 level, an ever-increasing shift of angler preference for fishing northern lakes will occur. The extent to which anglers will move northward will depend upon how rapidly the presently isolated northern lakes become readily accessible. Many of the accessible lakes in the north are currently subject to a relatively high level of angling pressure. On some lakes, the displacement of commercial fishing by an angler fishery may be expected.

A shift in the distribution of angling effort in the province has been occurring since 1967, due to decreased fishing success in the south, better roads and access to northern lakes, or to a combination of these and other factors. In 1967, the greatest percentage of anglers fished in the Whiteshell Provincial Park area, while the fewest number fished in the northern region (Fig. 27). The most notable changes in angler effort have been in these two regions. Anglers fishing in the Whiteshell have decreased from 30 per cent in 1967 to 13 per cent in 1980. The largest increase in angler pressure has been in the northern region. In 1967, 15 per cent of anglers polled in Manitoba indicated they had fished in the northern region. By 1980, this figure had grown to 26 per cent (Fig. 27). Between 1969 and 1972, the most preferred area of sport fishermen was the southern region. In these years, 29 to 35 per cent of the anglers were fishing in the south. A major shift to the northern region occurred between 1972 and 1980. During this period, the percentage of anglers fishing on northern lakes has gone from 17 to 26 per cent. The percentage of anglers fishing in the central region has increased by about four per cent since 1972.

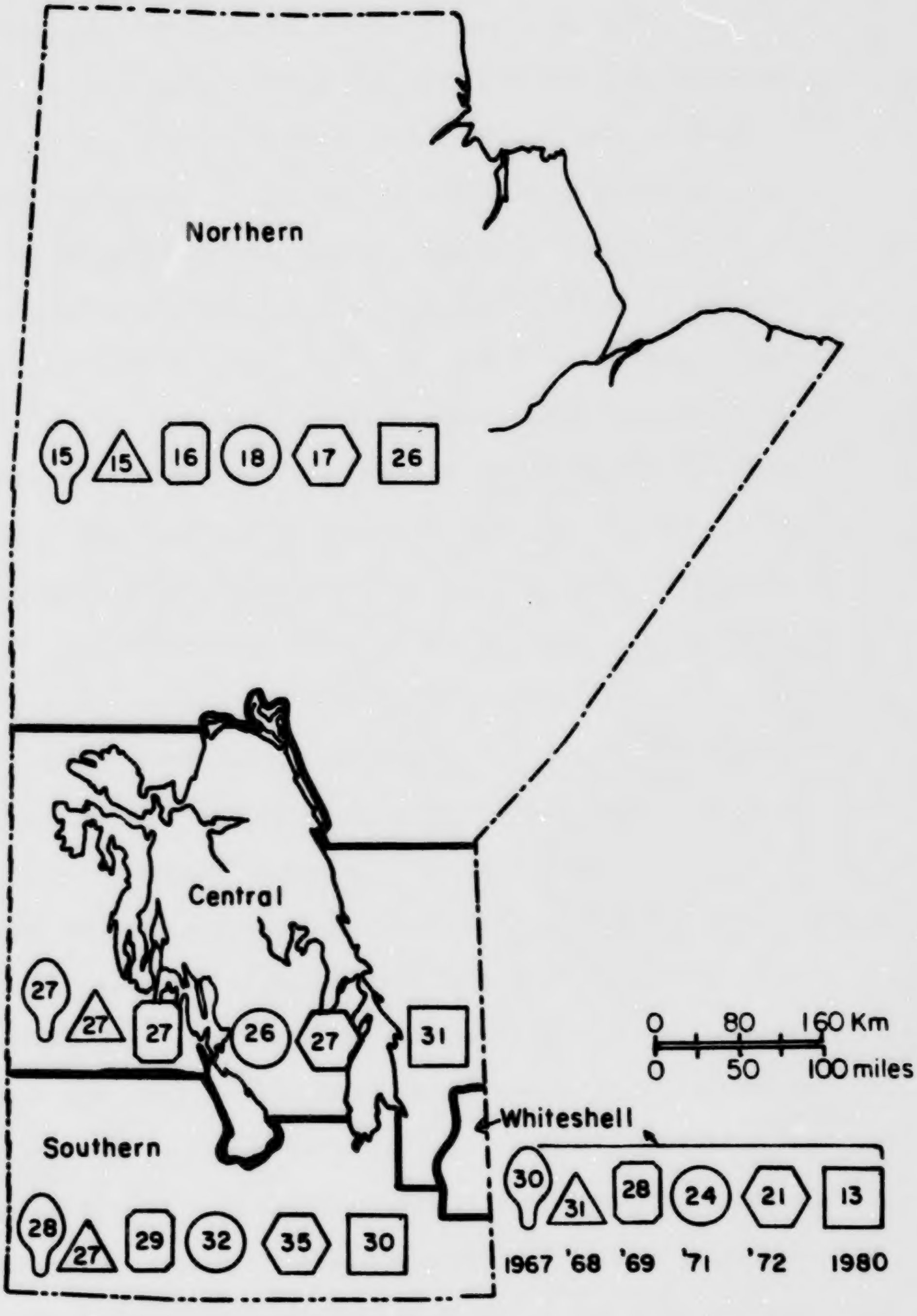

Fig. 27. The percentage distribution of anglers fishing in the different regions of Manitoba, 1967 - 1980.

Commercial Fishing

The total annual harvest of whitefish, walleye, sauger and northern pike from Manitoba waters has averaged 9.2 million kg between 1950-1980. The average annual harvest of the above four species from 1976 to 1980 has been 10.6 million kg. The long term sustainable yield of these species is probably around the 10 million kg yr^{-1} level. Catches in earlier years, although somewhat less than 10 million kg, were probably higher than reported. This is because prior to 1977, recorded data on fish catches were of marketed quantities only. Since the marketed quantities included some partially processed fish (eg. dressed or headless-dressed), they do not accurately reflect actual landings by the commercial fishery. Since 1977, commercial fish landings have been recorded as round or whole weights of fish. The long term sustainable yield of 10 million kg yr^{-1} of the four primary commercial species applies only to lakes presently fished and does not include the potential of other lakes as yet untapped.

The above basically assumes a "status quo" situation in the future development of the commercial fishing industry in Manitoba. The rapid growth and expansion experienced in the commercial fishing industry during the first half of this century has stopped and commercial catches now appear to be more or less in a state of equilibrium. If there is any further growth in Manitoba's commercial fishing industry, it will likely be due to further development in the marketing of less desirable or coarse fish species (eg. suckers, burbot, carp, etc.). However, for the purpose of simplifying the following discussions, it has been assumed there will be no future increase in the commercial harvests of whitefish, walleye, sauger and pike from Manitoba waters and will remain fixed at approximately 10 million kg yr^{-1} over the next two decades.

Summary of Estimated Potential Yields and Projected Demands

As previously mentioned, the current estimated potential harvest of whitefish, walleye, sauger and pike is approximately 17.4 million kg yr^{-1}. Potential yields from northern waterbodies less than 500 ha in size have been excluded, since most of these lakes are not readily accessible nor does it appear they will be for the foreseeable future. High transportation costs, as well as other factors (eg. *Triaenophorus* infestation, mercury contamination, a preponderance of coarse fish, etc.) are major deterrents to commercial fishing operations on these small lakes. The yield potential of many of these small lakes is also in question. Many northern lakes, especially the smaller waterbodies, are shallow and located in granite topography. Theoretical yields from such waters may be considerably overestimated due to a combination of factors such as severe climatic conditions, poor edaphic conditions, and adverse morphometric characteristics.

The total demand for the four primary fish species (whitefish, walleye, sauger and pike) is expected to reach the estimated available potential by 1995 and possibly as early as 1990 depending upon what assumptions are made in determining demand. Two scenarios are depicted in Fig. 28. These scenarios are based on the least and the greatest demands on the freshwater fish resource, as previously presented in tabular form.

Fig. 28(a) illustrates the least demand as described by the following assumptions:

(i) a domestic fish harvest of 35 kg per capita for northern native communities only.

(ii) a sport fish harvest by an angler population estimated from a linear regression analysis of angling licence sales.

(iii) a commercial harvest of 10 million kg yr^{-1}, which is the long term (1950-1980) average catch of prime species

Fig. 28(b) shows the greatest demands on Manitoba's fish resource assuming:

(i) a domestic harvest of 46 kg per capita for all native communities in Manitoba

(ii) an exponentially increasing sport fish harvest

(iii) a commercial harvest of 10 million kg yr^{-1} of prime fish species

Other combinations of demands would show harvests somewhere between the two scenarios presented in Fig. 28.

Increased demands on Manitoba's fish resources are evident in the domestic and sport fisheries. These projected increases were based on past trends which were influenced by contemporary social and economic conditions. Future demands by sport and domestic fishermen will undoubtedly also depend on prevailing socio-economic factors. However, the manner in which such factors could affect fishing demands

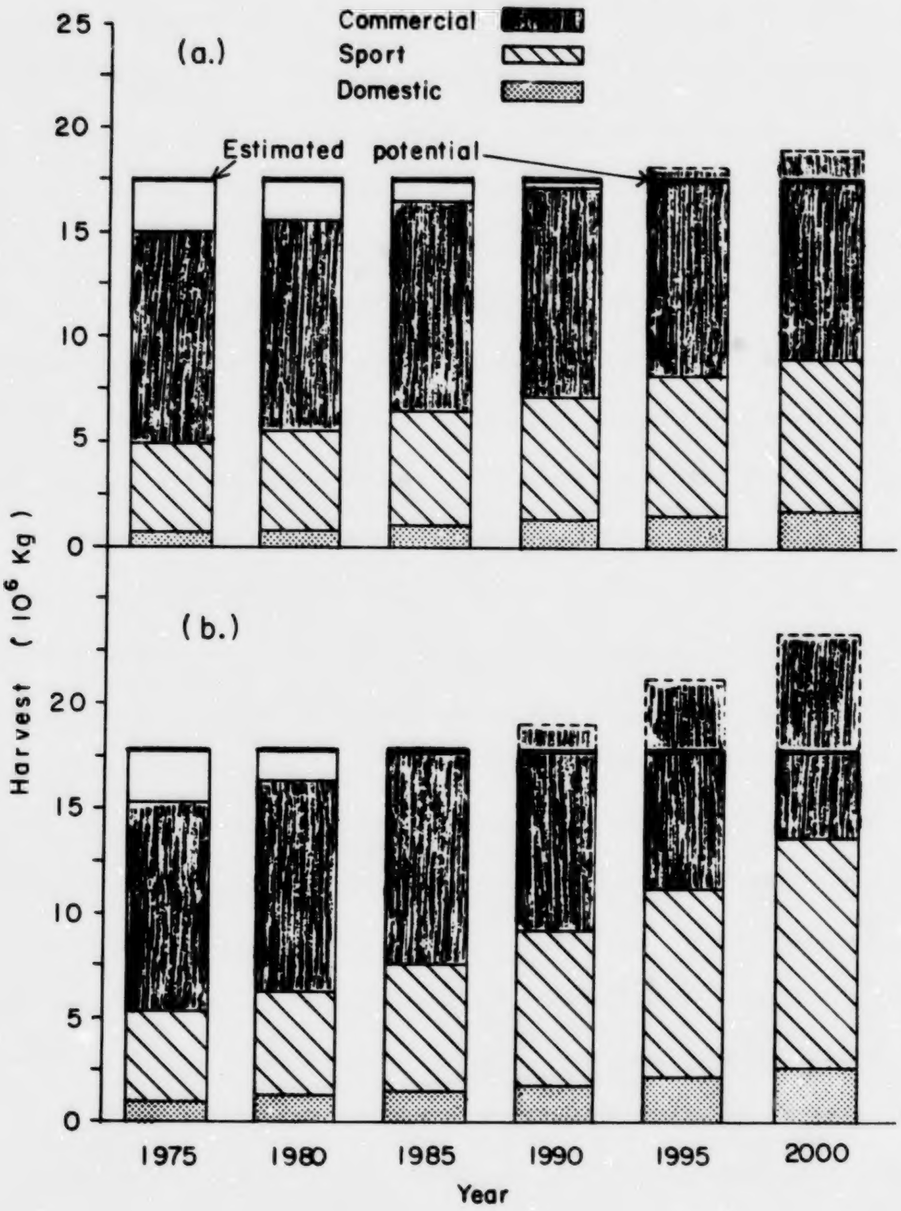

Fig. 28. (a) Total estimated potential supply and scenario showing the minimum harvest demands estimated to occur for the preferred species, 1975 - 2000.

(b) Total estimated potential supply and scenario showing the maximum harvest demands estimated to occur for the preferred species, 1975 - 2000.

could vary. For example, the high costs of angling equipment, travel, etc., could prevent many would-be enthusiasts from taking up the sport. Conversely, a persistent depressed economy could result in many people surrendering more costly recreational pursuits in exchange for angling. Domestic fishing, especially in the more remote northern communities, would most probably increase in a worsening economic situation. An increased reliance on locally produced fish would reduce dependance on more expensive food commodities shipped from other parts of the country or the continent. This development could change the economic outlook of the commercial fishing industry entirely.

Information presented in Fig. 28 does not include any future growth in the commercial fish harvest from Manitoba's waters. Commercial catches in these scenarios are projected to remain static over the next two decades. There has, however, been some modest growth in Manitoba's commercial fish production in recent years. This growth has resulted from an expansion of sales to Europe and other overseas markets. Traditionally, virtually all of Manitoba's exported fish was destined for U.S. markets. Recent sizeable export shipments by FFMC have included whitefish to Poland, large pike to France, walleye and sauger fillets to West Germany and Austria and mullets to Great Britain and Africa. Within the past 5 years, overseas sales of fish by the Freshwater Fish Marketing Corporation have increased from 16 to 25 per cent of the total fish sales (B. Popko, pers. comm.). The demand for freshwater fish by foreign commercial markets may increase even more in the next 20 years. Pitcher and Hart (1982) indicate that FAO estimates the world requirement for fish will reach 110 million tons yr^{-1} by

2000. This represents a 57 per cent increase over present demands. Although most of this production comes from the oceans, the world's ocean fisheries for traditional species are at or near their total potential yields. Consequently, more emphasis could be directed to the increased development of freshwater fisheries. To some extent this trend is already developing. Many third world countries are seeking the scientific advice of such countries as Canada and the U.S.A. in the development of their inland fisheries resources. Significant increases in commercial markets for freshwater fish could result in demands exceeding the available supply of fish in Manitoba much sooner than anticipated.

PART VI

CONCLUDING REMARKS

The principal conclusion drawn from the foregoing analysis of Manitoba's freshwater fisheries resources is that if future demands for fish increase as projected, without any effective intervention on the part of management, the total potential supply of prime fish species will be exceeded within the next two decades. This conclusion does not seem at all unreasonable. It has already been observed by Loftus _et al_. (1980) that demands have surpassed fish supplies in all of the more accessible parts of Ontario, as well as the rest of Canada. Documented information on a number of Manitoba's commercial and sport fisheries (eg. Davidoff _et al_. 1971, Davidoff 1978, and Lysack 1981) and past experiences have shown that some fish stocks have already been exploited beyond their maximum potential. Violently fluctuating catches, progressive declines in catch, the demise of older age classes, increased growth rates, increasing mortality rates, and marked shifts in species composition, all of which are symptomatic of overexploitation, have been observed over the past two decades in the fisheries on lakes located in the populated and accessible areas of Manitoba.

Estimates of fish producing capabilities of Manitoba waters, as presented in this report, are admittedly crude and could be much improved. Refinements to the estimation of supply would be time consuming, difficult and likely expensive, since it would require a more precise measure of the water area and an extensive inventory of the small (< 500 ha) northern lakes to determine their fish producing capacity. To some extent, such inventories could be accomplished using remote sensing methods described by Mallor (1981) for Alaskan lakes. For many reasons, it is also difficult or risky to predict the future demands on fish in Manitoba. Demand is influenced by numerous social and economic factors, such as discussed by Crook (1974), and these may interact or react in ways which are impossible to predict. Despite shortcomings in the data, the authors feel that the supply and demand estimates are good first approximations and reasonably accurate. These estimates indicate that there is no large surplus of the more desirable fish species available in the waters currently being fished. Although there are still some untapped sources of supply, these occur in the smaller northern lakes and may, for reasons previously discussed, be limited.

There can be no doubt that Manitoba's fisheries resources will have to face ever-increasing demands on them. These demands may come both from within and external to the provincial boundaries. The continued growth of world population will increase the need for fish. The world demand for food is expected to double by the year 2000 (FAO 1974). The world consumption of fish has grown at a faster rate than the human population (Robinson 1973). People in many of the Third World countries, as well as in developed countries such as the Soviet Union and Japan, rely almost exclusively on fish as the major source of animal protein in their diet. Fish must also be recognized as a trade commodity of growing economic importance. For example, in 1950 only

21 per cent of the total world's fish production entered into international trade; by 1968, this figure had grown to 45 per cent (Royce 1972). Regier (1978) suggests that these growing demands on fish resources, at least for the most preferred species, cannot be entirely met by the world's marine fisheries. From a commercial standpoint, full development of the marine fisheries will result in a greater emphasis on expanding fisheries production from freshwater. The development of such a trend has already begun to manifest itself. Historically, the bulk of commercial fish production from Manitoba was destined for U.S. markets. It is only in recent years that there has been a development of overseas markets for freshwater fish. These markets are mainly in Europe, but Third World countries are also involved. It is significant to note that these markets have developed even after the oil embargos of 1973, which caused a major increase in energy costs. Domestic consumption of fish may also increase in the near future. Recent increases in the transportation of agricultural commodities in western Canada may well cause significant increases in the cost of red meats and poultry to the point where locally produced fish are more attractive to the consumer. This may be particularly applicable to Manitoba, given the close proximity of a major center to the largest commercial fishery in the Province.

Irregardless of what changes may transpire in the commercial fishing industry, the continued growth in recreational fishing will assuredly place increasing demands on Manitoba's fish resources. We may expect unabated growth in the numbers of both resident and non-resident anglers fishing in Manitoba. There seems to be no reason to assume that the increase in resident anglers will not continue for the next two decades. Population pressures and the ongoing loss in high quality fishing opportunities in the U.S. will undoubtedly also maintain the growth in the non-resident angler population so long as good fishing opportunities exist in Manitoba.

Since anglers generally pursue the same species sought by commercial fishermen, direct and increasing competition between the two user groups for a limited or finite resource can be anticipated. With the first appearances of depletion of the preferred species, serious conflicts may become prevalent. Resource depletion and commercial/recreational conflicts may be circumvented for a time by the judicial allocation of the resource. However, if the relative economic values of commercial and recreational fishing without access limitations are considered, optimal regulation (i.e. allocation) may require, as Anderson (1980) indicated, the prohibition of one type of fishing. In most cases, this would mean that recreational fisheries would prevail because of their greater economic returns. The sanction of solely a recreational use of fish resources should, however, be considered in light of its ecological implications (Dill 1980). Anglers select or primarily catch species at the top of the aquatic food chain and leave the rest of the fish community virtually untouched. This may result in a shift in the fish community to species which are perhaps somewhat more productive, but of considerably less economic value.

Aside from commercial and recreational demands, Manitoba's fish resources are also being assailed by other human activities which may cause the direct or indirect destruction of fish and fish habitat. These activities in the Manitoba scene encompass such things as municipal and industrial water use, mining, agricultural land-use practices, irrigation, drainage, flood control, hydroelectric and thermal power generation, water-based transportation, urban development, forestry practices, linear developments (eg. roads, pipelines, transmission lines) and wildlife developments. Activities which involve water management (i.e. hydroelectric development, drainage, flood control, etc.) and liquid waste disposal pose the greatest number of problems, and in some cases the most difficult and costly, to the management of fish resources in Manitoba. Unlike commercial and recreational demands, these cultural activities have the potential to not only change the character of the fish resource, but may also cause a net loss in fish production potential. Increased human populations and contingent development may therefore result in a diminution of the total fish resource.

The information presented in this report underlines the need for caution in the present and future management of Manitoba's fisheries. The problems and challenges faced in the management of Manitoba's fish resources, however, are not unique. They have been discussed at greater length and in a much broader context by such authors as Regier (1976), Loftus (1976), and Harvey (1976). Future management thrusts will have to involve new and innovative methods based on sound ecological/biological and socio-economic information. An important component of this management must be greater emphasis on fish habitat protection.

In conclusion, it must be recognized that that complexity of social and political affairs make it difficult to be certain of the course of future events. The close surveillance of demands on Manitoba's fish resources and continued monitoring of fish stocks will therefore be necessary in order to detect significant changes in trends and to make the required adjustments in fisheries management policy and action.

PART VII

ACKNOWLEDGEMENTS

The authors wish to thank all individuals who gave assistance in the development of this report. Our requests for specific information were fulfilled by Fred Toll from the Manitoba Health Services Commission, Neil Douglas from the Manitoba Department of Economic Development and Tourism, and various individuals from the Department of Natural Resources, Fisheries Branch. These people were Don McDonald from the Interlake regional office, Jerry Edwards and Trevor Smith from the Western regional office and Rich Peters from Head Office in Winnipeg.

Special appreciation is extended to Barb Bean and Merle McTaggart who typed this report.

PART VIII

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PART 1X

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PART X

APPENDICES

Appendix I. List of source documents from which data used within this report were extracted. Documents are listed in alphabetical order of authors name.

Reference number	Author	Year	Source document title and origin
1	Adams, G. F. (Chairman), *et al*.	1976	First report of the fisheries working group for the northern plan. Draft report of Fisheries Steering Committee (unpublished). 161pp.
2	Anonymous (Gov't of Canada)	Annual	Annual statistical review of Canadian fisheries Vols. 1, 9 and 11.
3	Anonymous (Prov. of Man.)	Annual	Dept. of Natur. Resour. Annual Reports, Fisheries Branch.
4	Anthony, L.	1971	An estimation of the annual fish producing potential in eight northern Manitoba lakes. Man. Dept. Mines, Natur. Resour. Fish. MS Rep. No. 70-9. 8pp.
5	________________	1972	An investigation of eight northern Manitoba lakes for commercial fishing. Man. Dept. Mines, Resour. and Envir. Manag., Fish. MS Rep. No. 72-13. 43pp.
6	________________	1974	The 1967 biological study and management program for Nejanilini Lake. Man. Dept. Mines, Resour. and Envir. Manag., Fish. MS Rep. No. 74-11. 63pp.
7	Bilan, M.	1974	Manitoba fisheries fact book. Dept. Mines, Resour. and Envir. Manag., Fish. Br.
8	Blunt, B. A.	1975	A limnological survey of White Lake, 1974. Man. Dept. Mines, Resour. and Envir. Manag., Fish. MS Rep. No. 75-8. 39pp.
9	________________	1975	Reed Lake south shore liminology study August, 1974. Man. Dept. Mines, Resour. and Envir. Manag., Fish. MS Rep. No. 75-10. 46pp.

Appendix I. (Cont'd)

Reference number	Author	Year	Source document title and origin
10	Cleugh, T. R.	1974	The hydrography of Southern Indian Lake: present conditions and implications of hydroelectric development. The Lake Winnipeg, Churchill and Nelson Rivers Study Board. 1971-1975. Appendix 5, Vol. 1. 195pp.
11	Crowe, J. M. E.	1973	Surveys of Bowden, Clarke, and Lily lakes, July, 1972. Man. Dept. Mines, Resour. and Envir. Manag., Fish. MS Rep. No. 73-7. 71pp.
12	________	1974	Limnological surveys of Conlin, Muhigan and Muningwari lakes, July, 1973. Man. Dept. Mines, Resour. and Envir. Manag., Fish. MS Rep. No. 74-8. 36pp.
13	Derksen, A. J.	1975	Churchill River Study (Missinipi Probe) Report No. 16. Dept. Mines, Resour. and Envir. Manag., Fish. Br., 256pp.
14	________		Unpublished data.
15	Derksen, A. J. and D. G. Gillies	1979	Biological surveys of Buffalo and Little Limestone lakes, 1973-1974. Man. Dept. Mines, Natur. Resour., and Envir. Manag., Fish. MS Rep. No. 79-47, 90pp.
16	Gaboury, M. N.	1982	Fish Stock Assessment of Burntwood Lake. Man. Dept. Natur. Resour., Fish. MS Rep. No. 82-15, 71pp.
17	Gaboury. M. N. and J. W. Patalas	1982	The fisheries of Cross, Pipestone and Walker lakes and the effects of hydroelectric development. Man. Dept. Natur. Resour., Fish. MS Rep. No. 82-14, 198pp.

Appendix I. (Cont'd)

Reference number	Author	Year	Source document title and origin
18	Gibson, R. J.	1969	East Blue Lake fisheries investigation, 1967-1968. Man. Dept. Mines and Natur. Resour., Fish. MS Rep. No. 69-7, 85pp.
19	Gibson, R. J. and L. J. Johnson	1969	A limnological investigation of George Lake (Whiteshell Provincial Park) in 1967. Man. Dept. Natur. Resour., Fish. MS Rep. No. 69-3, 48pp.
20	Hagenson, I. and J. F. O'Connor	1978	A creel census of Gods Lake, 1974 and 1975. Man. Dept. North. Affairs, Renew. Resour. and Tran. Serv., Fish MS Rep. No. 78-57, 66pp.
21	________	1978	Fisheries inventory and lake classification Whiteshell Provincial Park , 1978. Man. Dept. Natur. Resour., Fish. MS Rep. No. 78-83, 113pp.
22	________	1979	A fisheries inventory of Obukowin and Aikens lakes, 1978. Man. Dept. Natur. Resour., Fish. MS Rep. No.79-75, 54pp.
23	________	1980	A fisheries inventory of Dogskin, Family, Viking and Vickers lakes, 1978. Man. Dept. Natur. Resour., Fish. MS Rep. No. 80-32, 64pp.
24	________	1981	A fisheries inventory of Harrop, Eardley, Weaver and Wrong lakes, 1978. Man. Dept. Natur. Resour., Fish. MS Rep. No. 81-24, 68pp.
25	Hangasjarvi, E. I.	1974	A limnological survey of Moak Lake, August, 1973. Man. Dept. Mines, Resour. and Envir. Manag., Fish. MS Rep. No. 74-12. 48pp.

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Reference number	Author	Year	Source document title and origin
26	Hughes, C. E.	1973	A preliminary limnological survey of Mystery Lake, 1972. Man. Dept. Mines, Resour. and Envir. Manag., Fish. MS Rep. No. 73-33. 40pp.
27	________	1975	A limnological survey of Ted Lake, 1974. Man. Dept. Mines Resour. and Envir. Manag., Fish. MS Rep. No. 75-9. 26pp.
28	Jardine, C. G. and J. S. Sigurdson	1981	A sport fisheries investigation of Sasaginnigak and Fishing Lakes, 1979. Man. Dept. Natur. Resour., Fish. MS Rep. No. 81-2, 68pp.
29	Kooymon, A. H.	1980	The acquatic resources of Riding Mountain National Park. Vol. V - Data on lakes.
30	Lysack, W.	1982	Fish stock assessment of lakes in the pulse fishing project. Man. Dept. Natur. Resour., Fish. MS Rep. No. 82-5, 307pp.
31	Peters, R. and C. Wall	Annual	Manitoba fisheries factbook. Man. Dept. Natur. Resour., Fish. Br.
32	Schlick, R. O.	1968	A survey of Molson Lake in 1967. Man. Dept. Natur. Resour., Fish. MS Rep. No. 68-4, 18pp.
33	________	1968	A survey of Sipiwesk Lake in 1966. Man. Dept. Natur. Resour., Fish. MS Rep. No. 68-5, 17pp.
34	________	1968	A survey of Setting Lake in 1967. Man. Dept. Natur. Resour., Fish. MS Rep. No. 68-6, 17pp.

Appendix I. (Cont'd)

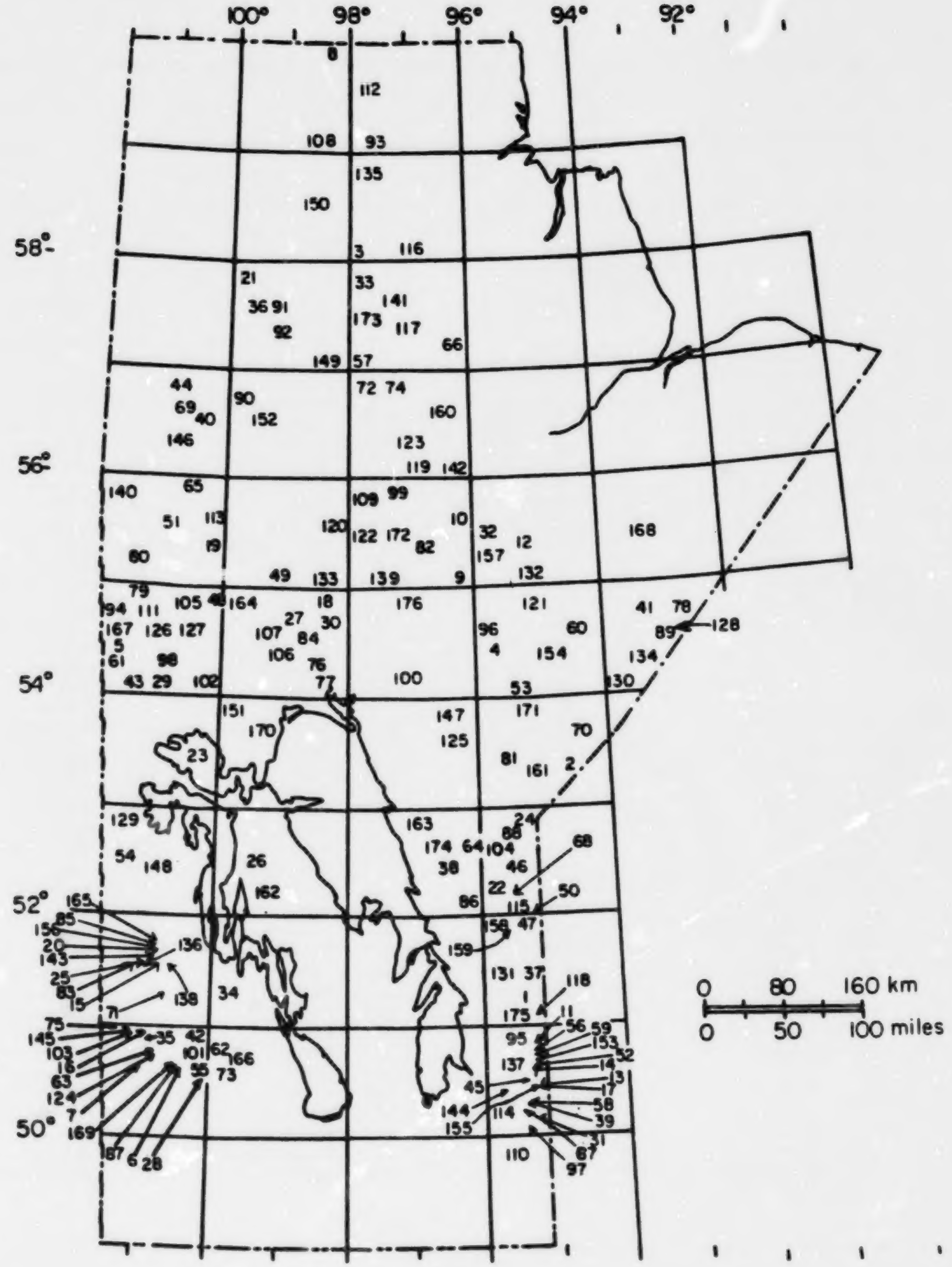
Reference number	Author	Year	Source document title and origin
35	Schlick, R. O.	1968	A survey of Twin Lake in 1967. Man. Dept. Natur. Resour., Fish. MS Rep. No. 68-7. 18pp.
36	________	1968	A survey of Split Lake in 1966. Man. Dept. Natur. Resour., Fish. MS Rep. No. 68-8, 21pp.
37	________	1968	A survey of Wekusko Lake in 1967. Man. Dept. Natur. Resour., Fish. MS Rep. No. 68-9, 22pp.
38	________	1968	A survey of Barrington Lake in 1967. Man. Dept. Natur. Resour., Fish. MS Rep. No. 68-10, 21pp.
39	________	1969	A survey of Paint Lake in 1967. Man. Dept. Natur. Resour. Fish. MS Rep. No. 68-11, 25pp.
40	________	1970	A fisheries survey of Egg Lake, 1968. Man. Dept. Mines, Natur. Resour., Fish. MS Rep. No. 70-2, 24pp.
41	________	1971	A fisheries survey of William Lake, 1969. Man. Dept. Natur. Resour., Fish. MS Rep. No. 70-3, 25pp.
42	________	1971	A fisheries survey of Wintering Lake, 1969. Man. Dept. Natur. Resour., Fish. MS Rep. No. 70-5, 22pp.
43	________	1971	A fisheries survey of Morton Lake, 1969. Man. Dept. Natur. Resour., Fish. MS Rep. No. 70-6, 23pp.
44	________	1971	A fisheries survey of File Lake, 1969. Man. Dept. Natur. Resour., Fish. MS Rep. NO. 70-7, 25pp.

Appendix I. (Cont'd)

Reference number	Author	Year	Source document title and origin
45	Schlick, R. O.	1971	A fisheries survey of Big Sand Lake, 1969. Man. Dept. Natur. Resour., Fish. MS Rep. No. 70-16, 23 pp.
46	________	1971	A fisheries survey of Landing Lake, Manitoba. Man. Dept. Natur. Resour., Fish. MS Rep. No. 70-21, 45pp.
47	________	1972	A fisheries survey of Naosop Lake, 1970. Man. Dept. Mines, Resour. and Envir. Manag., Fish. MS Rep. No. 71-3, 22pp.
48	________	1973	Lake Athapapuskow creel census in 1968. Man. Dept. Mines, Resour. and Envir. Manag., Fish. MS Rep. No. 73-13, 19pp.
49	________	1973	Mitchell Lakes survey, 1968. Man. Dept. Mines, Resour. and Envir. Manag., Fish. MS Rep. No. 73-15, 18pp.
50	________	1973	Survey of Pothier Lake, 1968. Man. Dept. Mines, Resour. and Envir. Manag., Fish MS Rep. No. 73-16, 19pp.
51	________	1973	A survey of Talbot Lake. Man. Dept. Mines, Resour. and Envir. Manag., Fish. MS Rep. No. 73-19, 20pp.
52	________	1973	A Survey of Goose Lake. Man. Dept. Mines, Resour and Envir. Manag., Fish. MS Rep. No. 73-20, 24pp.
53	________	1977	A fisheries survey of Kississing, 1968 and 1973. Man. Dept. Renew. Resour. and Trans. Serv., Fish. MS Rep. No. 77-41, 23pp.

Appendix I. (Cont'd)

Reference number	Author	Year	Source document title and origin
54	Schlick, R. O.	1978	A fisheries survey of Clearwater Lake, 1970. Man. Dept. Renew. Resour. and Trans. Serv., Fish. MS Rep. No. 78-3, 26pp.
55	________	1978	A fisheries survey of Kisseynew Lake, 1973 and 1974. Dept. Renew. Resour. and Trans. Serv., Fish. MS Rep. No. 78-4, 17pp.
56	________	1978	A fisheries survey of Gods Lake, 1973. Man. Dept. Renew. Resour. and Trans. Serv., Fish. MS Rep. No. 78-5, 25pp.
57	________	1978	Stevenson and Pelican lakes fisheries survey, 1973. Man. Dept. Renew. Resour. and Trans. Serv., Fish. MS Rep. No. 78-39, 38pp.
58	________	1979	A fisheries survey of Waskaiowaka Lake, 1972. Man. Dept. Mines, Natur. Resour., Fish, MS Rep. No. 79-61, 29pp.
59	Valiant, H.	person. comm.	
60	Wickstrom, R. O. and G. L. Merner.	1970	Commercial fishing inventory of northern Manitoba Lakes. Man. Dept. Mines, Natur. Resour., Fish. MS Rep. No. 69-12, 51pp.



Appendix II (a). Location of lakes from which MEI yield potential information was gathered. See accompanying list to match the lake number to lake name.

Appendix II (b). **List of lakes names corresponding to lake numbers shown on accompanying figure.**

Lake							
No.	**Name**	**No.**	**Name**	**No.**	**Name**	**No.**	**Name**
1	Aikens	45	Euclid	89	Little Stull	133	Setting
2	Ankle	46	Ewart	90	MacBride	134	Sharpe
3	Ashley	47	Family	91	Mackerracher I	135	Shethanei
4	Aswapiswannan	48	File	92	Mackerracher II	136	Shilliday
5	Athapapuskow	49	Fish	93	MacLeod	137	Shoe
6	Audy	50	Fishing	94	Manistikwan	138	Singush
7	Baldy	51	Flatrock	95	Manigotagan	139	Sipiwesk
8	Baralzon	52	Flinstone	96	Max	140	Sisipuk
9	Bear	53	Fairy Rock	97	Meditation	141	Small
10	Bearhead	54	Float Island	98	Mitchell	142	Split
11	Beresford	55	Fourth Bead	99	Moak	143	Spray
12	Bigstone	56	Garner	100	Molson	144	Springer
13	Birse	57	Cauer	101	Moon	145	Spruce
14	Black	57	George	102	Moose	146	Stag
15	Blue	59	Gem	103	Moose	147	Stevenson
16	Bobhill	60	Gods	104	Morfee	148	Swan
17	Booster	61	Goose	105	Morton	149	South Indian
18	Bowden	62	Grayling	106	Muhigan	150	Tadoule
19	Burntwood	63	Gunn	107	Muningwari	151	Talbot
20	Black Beaver	64	Harrop	108	Munro	152	Ted
21	Big Sand	65	Highrock	109	Mystery	153	Tooth
22	Carr-Harris	66	Hogg	110	Mud Turtle	154	Touchwood
23	Cedar	67	Horseshoe	111	Naosap	155	Tulabi
24	Charron	68	Horseshoe	112	Najanalini	156	Two Mile
25	Childs	69	Hughes	113	Nelson	157	Utik
26	Chitek	70	Island	114	Numao	158	Vickers
27	Clarke	71	Jackfish	115	Night Owl	159	Viking
28	Clear	72	Jensen	116	North Knife	160	Waskaiowaka
29	Clearwater	73	Katherine	117	North Indian	161	Wass
30	Conlin	74	Kisak	118	Obukowin	162	Waterhen
31	Crowduck	75	Kingdon	119	Orr	163	Weaver
32	Cuddle	76	Kiskitto	120	Ospwagon	164	Wekusko
33	Currie	77	Kiskittogisu	121	Oxford	165	Wellman
34	Dauphin	78	Kistigan	122	Paint	166	Whirpool
35	Deep	79	Kisseynew	123	Pearson	167	White
36	Denison	80	Kississing	124	Peden	168	Whitefish
37	Dogskin	81	Knight	125	Pelican	169	Whitewater
38	Eardley	82	Landing	126	Pothier	170	William
39	Echo	83	Langen	127	Reed	171	Willow
40	Eden	84	Lily	128	Rorke	172	Wintering
41	Edmund	85	Line	129	Red Deer	173	Wood
42	Edwards	86	Long	130	Red Sucker	174	Wrong
43	Egg	87	Long	131	Sasaginnisk	175	Wallace
44	Elizabeth	88	Lynx	132	Semple	176	White Rabbit

Appendix III. Morpho-edaphic indices (MEI) and estimated fish yields of lakes in the north region of Manitoba.

Lake	Location		Depth	TDS	MEI	Est. yield	Source
	Latitude	Longitude	(m)	(mg/ℓ)		(kg ha^{-1}yr^{-1})	document
Ashley	$58^{0}06'$	$97^{0}48'$	3.7	44.5	12.03	4.19	4 & 5
Baralzon	$60^{0}00'$	$98^{0}03'$	6.9	19.2	2.78	2.18	4 & 5
Big Sand	$57^{0}45'$	$99^{0}\ 45'$	7.9	46.0	5.80	3.03*	45
Currie	$57^{0}46'$	$97^{0}33'$	4.3	75.1	17.47	4.95	31
Denison	$57^{0}30'$	$99^{0}30'$	4.8	41.3	8.60	3.61	30
Gauer	$57^{0}00'$	$97^{0}50'$	6.6	93.9	14.23	4.52*	4 & 5
Hogg	$57^{0}16'$	$96^{0}06'$	1.8	41.0	22.78	5.57	31
Macherracher I	$57^{0}29'$	$99^{0}21'$	5.2	58.3	11.21	4.06	30
Mackerracher II	$57^{0}29'$	$99^{0}21'$	5.3	43.0	8.11	3.51	30
MacLeod	$59^{0}11'$	$97^{0}35'$	2.7	19.9	7.40	3.37*	4 & 5
Munro	$59^{0}06'$	$98^{0}27'$	-	-	-	3.36	14
Nejanilini	$59^{0}33'$	$97^{0}48'$	7.9	27.0	3.40	2.39	6
North Knife	$58^{0}05'$	$97^{0}05'$	9.5	79.2	8.34	3.56	4 & 5
North Indian	$57^{0}20'$	$97^{0}20'$	6.4	72.4	11.31	4.08*	4 & 5
Shethanei	$58^{0}49'$	$97^{0}50'$	7.0	31.5	4.50	2.70	4 & 5
Small	$57^{0}41'$	$97^{0}20'$	6.4	78.0	12.19	4.22	31
South Indian	$57^{0}00'$	$98^{0}30'$	9.2	64.0[1]	6.96	3.29	10
Tadoule	$58^{0}26'$	$98^{0}20'$	4.1	20.0	4.88	2.80	31
Whitefish	$55^{0}34'$	$93^{0}13'$	2.9	62.3	21.48	5.43	30
Wood	$57^{0}29'$	$97^{0}45'$	11.3	88.0	7.79	3.45	31

* Actual yields are presented in Appendix 6

[1] Yearly averages from major limnological stations.

Appendix IV. Morpho-edaphic indices (MEI) and estimated fish yields of lakes in north-central Manitoba. Lakes marked with an asterisk are those for which actual fish yields are listed in Appendix VII.

Lake	Location		Depth	TDS	MEI	Est. yield	Source
	Latitude	Longitude	(m)	(mg/ℓ)		(kg $ha^{-1}yr^{-1}$)	document
Aikens	$51^{0}12'$	$95^{0}20'$	19.6	74.0	3.80	2.51	22
Ankle	$53^{0}47'$	$94^{0}05'$	7.1	50.3	7.08	3.31	30
Aswapiswanan	$54^{0}28'$	$95^{0}28'$	2.8	77.3	27.61	6.07*	30
Athapapuskow	$54^{0}43'$	$101^{0}38'$	16.1	259.0	16.10	4.73	48 & 31
Barrington	$56^{0}55'$	$100^{0}15'$	9.1	66.0	7.25	3.35*	38
Bear	$55^{0}08'$	$96^{0}00'$	1.6	66.5	41.6	7.29*	31
Bearhead	$55^{0}33'$	$96^{0}10'$	2.1	77.0	36.67	6.89*	30
Bigstone	$55^{0}17'$	$95^{0}35'$	1.9	70.5	37.11	6.93	31
Bowden	$54^{0}56'$	$98^{0}36'$	7.0	-	-	5.34	11
Burntwood	$55^{0}29'$	$100^{0}07'$	2.7	81.7	30.26	6.33	16
Carr-Harris	$52^{0}21'$	$95^{0}53'$	1.9	56.0	29.47	6.25	31
Cedar	$53^{0}30'$	$100^{0}10'$	4.6	260.0	56.52	8.36*	31
Charron	$52^{0}44'$	$95^{0}15'$	17.8	31.0	1.74	1.77*	31
Clarke	$54^{0}45'$	$98^{0}43'$	7.9	120.0	-	5.02	11 & 31
Clearwater	$54^{0}05'$	$101^{0}00'$	13.1	230.8	17.62	4.97	54
Conlin	$54^{0}45'$	$98^{0}40'$	6.9	-	-	7.62	12
Cuddle	$55^{0}25'$	$95^{0}47'$	7.8	73.0	9.36	3.75*	30
Dogskin	$51^{0}43'$	$95^{0}12'$	5.0	56.0	11.09	4.04	23
Eardley	$52^{0}32'$	$96^{0}06'$	4.0	49.0	12.25	4.23	24
Eden	$56^{0}38'$	$100^{0}15'$	6.6	-	3.87	2.53*	13
Edmund	$54^{0}45'$	$93^{0}15'$	1.5	90.0	60.0	8.59	31 & 14
Egg	$54^{0}22'$	$101^{0}26'$	10.7	228.0	21.31	5.41*	40

Appendix IV. (Cont'd).

Lake	**Location**		**Depth**	**TDS**	**MEI**	**Est. yield**	**Source**
	Latitude	**Longitude**	**(m)**	**(mg/ℓ)**		**(kg ha^{-1}yr^{-1})**	**document**
Elizabeth	$56^{0}47'$	$100^{0}20'$	3.6	-	4.88	2.80	13
Ewart	$52^{0}26'$	$95^{0}49'$	1.9	61.0	32.11	6.50	31
Fairy Rock	$54^{0}00'$	$95^{0}45'$	6.6	89.0	13.49	4.41*	30
Family	$51^{0}54'$	$95^{0}27'$	4.0	78.0	18.46	5.08*	23
File	$54^{0}53'$	$100^{0}20'$	11.9	57.0	4.79	2.78	44
Fish	$55^{0}00'$	$98^{0}54'$	3.7	80.0	21.62	5.45*	31
Fishing	$52^{0}10'$	$95^{0}27'$	11.1	65.0	5.86	3.04	28
Flatrock	$55^{0}37'$	$100^{0}47'$	-	-	-	5.30	14
Gods	$54^{0}40'$	$94^{0}15'$	13.2	98.0	7.40	3.38*	20 & 56
Goose	$54^{0}28'$	$101^{0}30'$	2.3	211.0	91.74	10.38*	52
Harrop	$52^{0}38'$	$96^{0}00'$	2.1	51.0	24.29	5.74	24
Highrock	$55^{0}37'$	$100^{0}47'$	-	-	-	3.79	14
Horseshoe	$52^{0}12'$	$95^{0}49'$	3.6	60.0	16.67	4.85	31
Hughes	$56^{0}48'$	$100^{0}25'$	8.8	-	-	2.77	13
Island	$53^{0}47'$	$94^{0}25'$	18.3	80.0	4.37	2.67*	31
Jensen	$56^{0}41'$	$97^{0}40'$	6.7	125.7	18.76	5.11	31
Kiask	$56^{0}46'$	$97^{0}24'$	6.7	148.8	22.21	5.51	31
Kiskitto	$54^{0}16'$	$98^{0}30'$	2.5	183.0	73.20	9.38*	31
Kiskittogisu	$54^{0}13'$	$98^{0}20'$	4.6	212.0	46.09	7.63*	31
Kistigan	$54^{0}37'$	$92^{0}35'$	-	-	-	1.57*	14
Kisseynew	$54^{0}58'$	$101^{0}35'$	5.6	59.0	10.54	3.95*	55
Kississing	$55^{0}10'$	$101^{0}20'$	6.3	51.0	8.10	3.52*	53
Knight	$53^{0}42'$	$95^{0}25'$	-	-	-	5.16	14
Landing	$55^{0}17'$	$97^{0}26'$	-	126.0	4.20	2.62*	46
Lily	$54^{0}41'$	$98^{0}43'$	-	-	-	8.60	11
Little Stull	$54^{0}37'$	$92^{0}35'$	-	-	-	4.37	14
Long	$52^{0}12'$	$96^{0}02'$	4.2	60.0	14.29	4.53	31

Appendix IV. (Cont'd).

Lake	Location		Depth	TDS	MEI	Est. yield	Source
	Latitude	Longitude	(m)	(mg/ℓ)		(kg ha^{-1}yr^{-1})	document
Lynx	$52^{0}32'$	$95^{0}47'$	1.6	57.0	35.63	6.81	31
MacBride	$56^{0}52'$	$99^{0}57'$	4.3	80.3	18.67	5.10*	30
Manistikwan	$54^{0}45'$	$101^{0}45'$	19.3	128.0	6.63	3.22	31 & 14
Max	$54^{0}33'$	$95^{0}58'$	4.4	62.7	14.25	4.52*	30
Mitchell	$54^{0}18'$	$101^{0}00'$	3.7	190.0	51.35	8.01	49
Moak	$55^{0}55'$	$97^{0}36'$	7.01	127.5	18.19	5.04	25
Molson	$54^{0}12'$	$96^{0}45'$	11.6	89.7	7.73	3.44*	32
Moose	$54^{0}05'$	$100^{0}10'$	-	-	-	2.80*	14
Morfee	$52^{0}28'$	$95^{0}56'$	1.8	55.0	30.56	6.36	31
Morton	$54^{0}50'$	$100^{0}27'$	9.9	84.0	8.48	3.59	43
Muhigan	$54^{0}33'$	$98^{0}47'$	1.3	-	-	8.92	12
Muningwari	$54^{0}36'$	$98^{0}50'$	3.3	-	-	6.00	12
Mystery	$55^{0}51'$	$97^{0}36'$	3.1	122.0	39.35	7.11	26
Naosop	$54^{0}51'$	$101^{0}24'$	3.7	94.0	25.41	5.85*	47
Nelson	$55^{0}44'$	$100^{0}00'$	-	-	-	6.18	14
Night Owl	$52^{0}06'$	$95^{0}38'$	4.0	60.0	15.0	4.63	31
Obukawin	$51^{0}04'$	$95^{0}11'$	1.6	64.5	41.10	7.25	22
Orr	$56^{0}07'$	$97^{0}11'$	1.8	92.0	51.11	7.99	31
Ospwagan	$55^{0}35'$	$98^{0}03'$	20.4	122.0	5.98	3.07	31
Oxford	$54^{0}51'$	$95^{0}37'$	-	-	-	3.36*	14
Paint	$55^{0}28'$	$97^{0}57'$	6.4	96.0	15.00	4.63*	39
Pearson	$56^{0}15'$	$97^{0}15'$	1.5	143.0	95.33	10.56	31
Pelican	$53^{0}50'$	$96^{0}08'$	3.6	102.0	28.33	6.15	57
Pothier	$54^{0}17'$	$101^{0}15'$	4.3	212.0	49.30	7.87	50
Reed	$54^{0}38'$	$100^{0}30'$	9.4	95.0	10.03	3.87*	9
Red Sucker	$54^{0}09'$	$93^{0}40'$	-	-	-	2.47*	14

Appendix IV. (Cont'd).

Lake	**Location**		**Depth**	**TDS**	**MEI**	**Est. yield**	**Source**
	Latitude	**Longitude**	**(m)**	**(mg/ℓ)**		**(kg ha^{-1}yr^{-1})**	**document**
Rorke	54°33'	92°30'	2.0	108.0	54.0	8.19	31
Sasaginniak	51°36'	95°39'	5.5	45.0	8.18	3.53	28
Semple	55°02'	95°38'	1.6	78.7	49.19	7.86	30
Setting	55°00'	98°30'	5.8	88.0	15.17	4.65*	34
Sharpe	54°24'	93°30'	-	-	-	4.71	14
Sipiwesk	55°05'	97°35'	11.0	196.0	17.82	5.00*	33
Sisipuk	55°45'	101°50'	18.6	54.0	-	3.74*	14
Split	56°08'	96°15'	7.0	170.0	24.29	5.74*	36
Stag	56°30'	100°25'	-	-	5.18	2.88*	13
Stevenson	53°55'	96°09'	4.8	79.0	16.46	4.82	57
Talbot	54°00'	99°55'	1.9	349.0	183.68	14.14*	51
Ted	56°30'	99°40'	3.4	280.0	82.40	9.89	27
Touchwood	54°29'	95°00'	-	-	-	3.36*	14
Utik	55°16'	96°00'	6.8	74.0	10.88	4.01*	31
Vickers	51°52'	95°54'	2.2	45.5	20.60	5.33	23
Viking	51°54'	95°49'	1.9	67.0	35.30	6.78	23
Wallace	51°52'	95°20'	2.8	24.5	8.75	3.64	31
Waskaiowaka	56°33'	96°23'	4.5	138.0	30.67	6.37	58
Wass	53°40'	95°25'	4.5	83.7	18.60	5.09	30
Weaver	52°45'	96°35'	2.0	58.5	29.25	6.23	24
Wekusko	54°45'	99°50'	7.9	97.1	12.29	4.23	37
White	54°42'	101°45'	4.0	120.0	29.69	6.27	8
White Rabbit	54°59'	97°20'	6.1	30.0	4.92	2.81	31
William	53°54'	99°21'	2.8	200.0	71.43	9.28	41
Willow	53°57'	95°25'	14.1	71.7	5.09	2.86	30
Wintering	55°23'	97°43'	5.2	116.0	22.31	5.52	42
Wrong	52°38'	96°12'	3.7	77.0	20.81	5.36	24

* Actual yields are presented in Appendix 7.

Appendix V. Morpho-edaphic indicies (MEI) and estimated potential fish yields of lakes in the south region of Manitoba.

Lake	Location		Depth	TDS	MEI	Est. pot. yield	Source
	Latitude	Longitude	(m)	(mg/ℓ)		$(kg\ ha^{-1} yr^{-1})$	document
Audy(647)	$50^{0}45'$	$100^{0}15'$	2.1	227	108.10	11.17	29
Baldy(258)	$50^{0}49'$	$100^{0}37'$	1.8	182	101.11	10.84	29
Beresford	$50^{0}52'$	$95^{0}14'$	3.0	46.7	15.57	4.71	31
Birse	$50^{0}24'$	$95^{0}20'$	6.7	56.8	8.48	3.59	31
Black	$50^{0}40'$	$95^{0}20'$	3.3	33.0	10.00	3.86	31
Black Beaver	$51^{0}46'$	$100^{0}53'$	1.9	152	80.00	9.76	59
Blue(east)	$51^{0}36'$	$100^{0}55'$	21.7	178	8.20	3.53	18
Bobhill(1602)	$50^{0}55'$	$100^{0}54'$	3.8	179	47.11	7.71	29
Booster	$50^{0}27'$	$95^{0}16'$	5.6	30.5	5.45	2.95	31
Childs	$51^{0}36'$	$101^{0}05'$	15.0	183.6	12.24	4.23	59
Clear(130 I)	$50^{0}41'$	$100^{0}00'$	11.6	216	18.62	5.10	29
Crowduck	$50^{0}08'$	$95^{0}15'$	7.5	118	15.73	4.73	21
Chitek	$52^{0}25'$	$99^{0}25'$	2.1	450	214.29	15.15	59
Dauphin	$51^{0}17'$	$99^{0}48'$	2.4	313	130.42	12.14	59
Deep(1575)	$50^{0}54'$	$100^{0}51'$	7.5	172	22.93	5.59	29
Echo	$50^{0}13'$	$95^{0}23'$	8.3	55	6.63	3.22	21
Edwards(1104)	$50^{0}55'$	$100^{0}03''$	2.2	74	33.64	6.63	29
Euclid	$50^{0}35'$	$95^{0}23'$	2.1	41.8	19.9	5.15	31
Flinstone	$50^{0}42'$	$95^{0}17'$	4.4	51.2	11.64	4.13	31
Float Island	$52^{0}31'$	$101^{0}37'$	5.1	165	32.35	6.52	59
Fourth Bead(952)	$50^{0}47'$	$100^{0}01'$	5.5	211	38.36	7.03	29

Appendix V. (Cont'd).

Lake	Location Latitude	 Longitude	Depth (m)	TDS (mg/ℓ)	MEI	Est. pot. yield (kg $ha^{-1} yr^{-1}$)	Source document
Garner	$50^{0}49'$	$95^{0}11'$	10.9	20	1.83	1.81	31
George	$50^{0}15'$	$95^{0}30'$	12.0	63.0	5.25	2.89	21
Gem	$50^{0}45'$	$95^{0}12'$	5.7	56.5	9.91	3.85	31
Grayling(786)	$50^{0}47'$	$99^{0}59'$	7.1	204.0	28.73	6.18	29
Gunn(1082)	$50^{0}52'$	$100^{0}32'$	1.2	307.0	255.83	16.40	29
Horseshoe	$50^{0}08'$	$95^{0}25'$	3.6	60.0	11.41	4.10	31
Jackfish	$51^{0}24'$	$100^{0}49'$	1.4	305.0	217.86	15.26	59
Katherine(114)	$50^{0}39'$	$99^{0}53'$	4.1	166.0	40.49	7.21	29
Kingdon(1950)	$50^{0}59'$	$101^{0}04'$	1.3	189.0	145.38	12.74	29
Langen	$51^{0}34'$	$101^{0}20'$	6.1	265.0	43.44	7.44	59
Line	$51^{0}48'$	$100^{0}55'$	1.6	160.0	100.00	10.79	59
Long(881)	$50^{0}47'$	$100^{0}19'$	4.4	275.0	62.65	8.75	29
Manigotagon	$50^{0}52'$	$95^{0}31'$	10.0	48.6	4.86	2.80	31
Meditation	$50^{0}06'$	$95^{0}27'$	3.4	69.0	20.29	5.30	21
Moon(1053)	$50^{0}53'$	$100^{0}03'$	4.2	132.0	31.43	6.44	29
Moose(1893)	$50^{0}53'$	$101^{0}03'$	3.0	214.0	71.33	9.28	29
Mud Turtle	$49^{0}54'$	$95^{0}36'$	1.5	83.5	55.67	8.31	21
Numao	$50^{0}10'$	$95^{0}38'$	11.7	76.0	6.50	3.19	21
Pelican	$52^{0}28'$	$100^{0}20'$	2.4	600.0	250.00	16.23	59
Peden(763)	$50^{0}45'$	$100^{0}31'$	1.9	352.0	185.26	14.20	29
Red Deer	$52^{0}56'$	$101^{0}20'$	2.7	305.0	112.96	11.39	59
Shilliday	$51^{0}35'$	$100^{0}56'$	6.7	217.0	32.39	6.52	59

Appendix V. (Cont'd).

Lake	**Location**		**Depth**	**TDS**	**MEI**	**Est. pot. yield**	Source
	Latitude	**Longitude**	**(m)**	**(mg/ℓ)**		**(kg ha^{-1}yr^{-1})**	document
Shoe	$50^{0}39'$	$95^{0}28'$	4.4	47.0	10.68	3.98	31
Singush	$51^{0}36'$	$100^{0}48'$	4.8	190.0	39.58	7.13	59
Spray	$51^{0}44'$	$100^{0}57'$	2.2	180.0	81.82	9.86	59
Springer	$50^{0}32'$	$95^{0}27'$	1.9	38.0	20.0	5.26	31
Spruce(1590)	$50^{0}54^{0}$	$101^{0}00'$	1.4	233.0	166.45	13.54	29
Swan Lake	$52^{0}30'$	$100^{0}45'$	2.3	416.0	180.87	14.05	59
Tooth	$50^{0}45'$	$95^{0}19'$	8.6	28.0	3.26	2.34	31
Tulabi	$50^{0}29'$	$95^{0}15'$	6.8	32.0	4.71	2.76	31
Two Mile	$51^{0}46'$	$100^{0}55'$	6.4	-	-	1.69	59
Waterhen	$52^{0}06'$	$99^{0}34'$	2.3	1000.0	434.78	20.77	59
Wellman	$51^{0}49'$	$100^{0}54'$	4.5	136.0	30.22	6.32	59
Whitewater(910)	$50^{0}47'$	$100^{0}24'$	1.4	353.0	252.14	16.29	29
Whirpool(198)	$50^{0}43'$	$99^{0}48'$	1.0	148.0	143.00	12.85	29

Appendix VI. Actual fish yields from lakes commercially fished in the north region of Manitoba, 1976 - 1980.

Lake	Location		Area	No. of years	Production	Range of Production
	Latitude	Longitude	ha	fished	kg $ha^{-1}yr^{-1}$	kg $ha^{-1}yr^{-1}$
Abram	$57^{0}55'$	$101^{0}08'$	1,008	1	0.59	
Big Sand	$57^{0}45'$	$99^{0}45'$	26,854	5	1.67	0.82 - 2.24
Brisebois	$57^{0}28'$	$100^{0}44'$	910	1**	3.71	
Carriere	$57^{0}23'$	$101^{0}49'$	402	2	3.71	2.47 - 4.94
Chatwin	$58^{0}34'$	$100^{0}48'$	3,266	2	0.66	0.36 - 0.96
Chipewyan	$58^{0}00'$	$98^{0}27'$	3,797	2	0.21	0.08 - 0.34
Chuipka	$57^{0}20'$	$100^{0}20'$	1,573	1	1.52	
Cross(Nelson R.)	E. of	$93^{0}27'$	45,941	5	0.82	0.09 - 1.33
Denison - Mackerracher	$57^{0}30'$	$99^{0}30'$	3,870	1	9.66	
Dunseath	$57^{0}03'$	$100^{0}45'$	2,016	4	2.30	0.17 - 3.47
Easton	$58^{0}10'$	$101^{0}00'$	1,810	1	3.99	
Gauer	$57^{0}00'$	$97^{0}50'$	25,860	3	0.70	0.33 - 1.00
Hjalmarson	$57^{0}41'$	$101^{0}13'$	2,339	4	2.83	1.37 - 4.18
Jordon	$57^{0}37'$	$100^{0}18'$	4,610	1	0.71	
Lac Brochet	$58^{0}56'$	$101^{0}33'$	25,305	2	1.65	0.75 - 2.55
Le Clair	$57^{0}23'$	$100^{0}13'$	2,250	3	1.69	0.32 - 3.60
McLeod	$57^{0}16'$	$98^{0}45'$	1,653	4	2.83	0.46 - 4.43
Melvin	$57^{0}03'$	$100^{0}14'$	3,387	2	2.00	1.76 - 2.23
Moss	$57^{0}38'$	$98^{0}44'$	1,371	1	1.22	
North Indian	$57^{0}20'$	$97^{0}20'$	20,223	4	1.82	0.25 - 2.66
Paskwatch	$57^{0}15'$	$101^{0}55'$	5,440	1**	0.13	
Reindeer	$57^{0}20'$	$102^{0}00'$	96,092	5	0.78	0.08 - 1.27
Robinson	$58^{0}43'$	$99^{0}12'$	6,619	1**	0.38	

Appendix VI. (Cont'd).

Lake	Location		Area	No. of years	Production	Range of Production
	Latitude	Longitude	ha	fished	kg ha^{-1}yr^{-1}	kg ha^{-1}yr^{-1}
Rock Island	58°15'	99°29'	2,018	1**	1.01	
Sandy	58°52'	100°06'	1,452	1	3.21	
South Indian	57°10'	98°30'	198,421	5	2.41	2.22 - 2.54
Stoney	58°51'	98°35'	12,764	1	0.02	
Thorsteinson	57°15'	97°30'	3,710	2	0.57	0.56 - 0.58
Wells	57°15'	101°00'	5,698	4	1.71	0.95 - 3.11
Wiskey Jack	58°23'	101°55'	10,697	1	0.87	
Whitefish, Elbow, Cox	55°34'	93°13'	5,807	1	0.13	
Wilkie	58°45'	98°17'	1,810	1**	1.51	

** experimental fishing

Appendix VII. Actual fish yields from lakes commercially fished in the north-central region of Manitoba, 1976 - 1980.

Lake	Location		Area	No. of years	Production	Range of Production
	Latitude	Longitude	ha	fished	kg ha^{-1}yr^{-1}	kg ha^{-1}yr^{-1}
Allen	56°04'	100°30'	3,347	3	1.37	0.44 - 2.25
Angling	53°55'	93°52'	6,475	2	1.53	1.00 - 2.06
Apeganau	55°35'	99°35'	2,298	3	1.46	0.36 - 3.10
Armstrong	55°43'	96°55'	2,859	4	2.47	0.39 - 3.61
Aswapiswanan	54°28'	95°28'	2,984	2	2.44	1.09 - 3.78
Atkinson	55°59'	94°48'	3,629	4	2.99	0.59 - 5.37
Baldock	56°33'	97°57'	13,716	2	0.62	0.25 - 1.00
Barrington	56°55'	100°15'	16,504	5	1.48	1.19 - 1.86
Batty	55°09'	100°40'	1,694	5	2.88	2.51 - 3.37
Bear	55°08'	96°00'	13,810	4	1.79	0.05 - 2.79
Bearhead	55°31'	96°10'	2,416	1	1.95	
Beaverhill	54°16'	94°59'	17,073	5	3.18	2.51 - 3.84
Begg	53°51'	95°21'	1,295	1	4.78	
Bennett	53°28'	96°05'	2,057	2	4.25	4.01 - 4.49
Bigstone - Knight	53°42'	95°44'	15,901	5	2.45	1.33 - 2.99
Bolton	54°16'	95°42'	7,294	3	2.20	1.33 - 3.85
Burntwood	55°22'	100°26'	16,597	4	2.16	0.92 - 3.86
Britton	55°55'	101°51'	2,097	2	0.72	0.56 - 0.88
Bruneau	55°01'	97°33'	1,452	5	3.13	0.61 - 5.67
Buckingham	55°48'	97°13'	1,036	1	0.49	
Butterfly	54°26'	97°16'	1,855	5	3.71	0.49 - 7.69
Cantin	53°27'	95°10'	3,468	1	1.64	
Cartwright - Hughes	56°30'	100°31'	1,774	1	0.31	

Appendix VII. (Cont'd).

Lake	Location		Area	No. of years	Production	Range of Production
	Latitude	Longitude	ha	fished	kg $ha^{-1}yr^{-1}$	kg $ha^{-1}yr^{-1}$
Cauchon, Archibald, Prud'Homme	$55^{0}30'$	$96^{0}27'$	12,139	5	5.05	2.33 - 8.02
Cedar	$53^{0}30'$	$100^{0}10'$	126,147	5	7.2	6.11 - 8.20
Charron	$52^{0}44'$	$95^{0}15'$	5,314	2	0.60	0.26 - 0.95
Chepil	$56^{0}52'$	$100^{0}36'$	490	1**	5.48	
Cousins	$56^{0}49'$	$98^{0}32'$	1,774	1	0.18	
Clearwater - Bracken	$53^{0}54'$	$99^{0}49'$	5,887	3	0.94	0.34 - 1.66
Colen	$54^{0}33'$	$95^{0}25'$	4,973	2	3.13	0.48 - 5.78
Cormorant	$54^{0}14'$	$100^{0}49'$	32,780	5	0.61	0.38 - 1.02
Costello	$56^{0}10'$	$100^{0}04'$	1,554	2	1.14	0.27 - 1.99
Cotton(Camping)	$55^{0}04'$	$96^{0}49'$	9,324	5	1.19	0.44 - 2.08
Craig	$56^{0}40'$	$101^{0}47'$	887	1	2.45	
Cuddle	$55^{0}25'$	$95^{0}48'$	3,626	2	0.51	0.14 - 0.89
Dafoe	$55^{0}44'$	$96^{0}15'$	2,460	5	3.34	2.55 - 4.37
Dobb	$53^{0}56'$	$95^{0}12'$	1,573	3	2.17	0.73 - 3.68
Dolomite	$54^{0}27'$	$100^{0}33'$	953	3	2.84	2.22 - 3.18
Dow	$53^{0}00'$	$100^{0}35'$	886	1	6.96	
Duck	$54^{0}52'$	$98^{0}11'$	4,557	1	3.47	
Dugas	$55^{0}04'$	$98^{0}00'$	912	3	3.30	2.54 - 3.91
Dyce	$54^{0}23'$	$100^{0}26'$	565	3	2.30	0.33 - 3.37
Eden	$56^{0}38'$	$100^{0}15'$	7,029	2	0.30	0.24 - 0.36
Edmund - Kenyon	$54^{0}45'$	$93^{0}15'$	12,300	5	3.71	2.48 - 4.36
Egg	$54^{0}22'$	$101^{0}26'$	5,698	4	1.25	0.18 - 2.16

Appendix VII. (Cont'd).

Lake	Location		Area	No. of years	Production	Range of Production
	Latitude	Longitude	ha	fished	kg ha^{-1}yr^{-1}	kg ha^{-1}yr^{-1}
Election	54°35'	101°13'	600	4	2.75	0.53 - 4.53
Elvyn - Wolf Pack	56°07'	101°02'	1,048	2	2.95	1.91 - 4.00
Family	51°54'	96°27'	10,986	3	0.71	0.57 - 0.81
Fay - Syme	54°59'	101°08'	806	4	5.30	4.94 - 6.97
Finch	56°34'	100°57'	726	1	5.03	
Fish	55°00'	98°54'	1,160	3	3.33	2.19 - 5.19
Flatrock, Highrock, Nelson	55°37'	100°47'	37,908	5	0.93	0.33 - 1.35
Fairy Rock	54°00'	95°25'	1,855	2	3.02	2.61 - 3.43
Florence	54°58'	101°57'	580	3	5.98	2.03 -11.84
Gods	54°40'	94°15'	104,763	5	0.65	0.46 - 0.88
Goose	54°28'	101°35'	12,950	5	1.91	1.39 - 2.35
Goose - Rochon	54°14'	94°33'	6,350	4	2.37	0.64 - 3.32
Goulet	55°24'	96°19'	3,145	5	2.19	1.03 - 2.77
Granville	56°18'	100°30'	45,584	5	1.56	1.07 - 1.95
Guthrie	55°17'	100°38'	3,508	5	4.74	4.16 - 5.33
Halfway	55°03'	98°24'	2,942	5	6.16	1.44 -10.34
Hayward	53°42'	93°43'	1,040	1	3.47	
Herblet	54°56'	99°54'	2,984	5	4.14	3.56 - 5.84
Hermon	55°11'	96°48'	550	2	5.92	4.86 - 6.98
High Hill	55°34'	95°42'	4,807	2	2.88	2.85 - 2.92
Hill	54°20'	98°53'	1,048	1**	9.03	
Hughes	56°48'	100°25'	960	1**	0.23	
Irene	56°43'	101°28'	180	1**	2.66	
Island	53°47'	94°25'	108,742	5	1.53	0.72 - 1.95

Appendix VII. (Cont'd).

Lake	Location		Area	No. of years	Production	Range of Production
	Latitude	Longitude	ha	fished	kg $ha^{-1}yr^{-1}$	kg $ha^{-1}yr^{-1}$
Joint	$54^{0}23'$	$95^{0}24'$	1,989	2	3.25	3.03 - 3.47
Kalliecahoolie	$54^{0}14'$	$95^{0}29'$	4,706	4	3.85	3.25 - 4.12
Kamuchawie	$56^{0}18'$	$102^{0}00'$	6,967	2	1.32	1.05 - 1.60
Kipahigan	$55^{0}20'$	$101^{0}55'$	10,111	5	2.75	1.97 - 3.77
Kiski	$54^{0}16'$	$98^{0}55'$	2,155	4	2.68	1.78 - 4.28
Kiskitto	$54^{0}16'$	$98^{0}30'$	15,540	5	0.78	0.63 - 1.06
Kiskittogisu	$54^{0}13'$	$98^{0}20'$	31,577	5	1.15	0.76 - 1.79
Kisseynew	$54^{0}58'$	$101^{0}35'$	7,662	5	3.64	2.86 - 4.80
Kississing	$55^{0}10'$	$101^{0}20'$	32,448	5	0.88	0.24 - 1.20
Kistigan	$54^{0}37'$	$92^{0}35'$	9,960	2	3.71	2.43 - 4.99
Knee	$55^{0}03'$	$94^{0}45'$	27,517	5	2.88	2.30 - 3.49
Landing	$55^{0}17'$	$97^{0}26'$	11,920	5	1.41	0.75 - 1.97
Laurie	$56^{0}35'$	$101^{0}57'$	7,770	2	1.21	0.72 - 1.70
Landry	$53^{0}48'$	$100^{0}52'$	2,486	5	2.91	0.81 - 4.09
Lawford	$54^{0}30'$	$96^{0}43'$	8,276	4	4.23	3.97 - 4.44
Leftrock	$56^{0}05'$	$98^{0}36'$	4,073	3	2.05	0.34 - 3.12
Limestone Point	$55^{0}07'$	$100^{0}32'$	2,863	5	4.58	2.28 - 7.12
Little Bolton	$54^{0}10'$	$96^{0}13'$	2,642	3	2.48	1.88 - 2.96
Little Limestone	$53^{0}45'$	$99^{0}20'$	3,600	1	1.11	
Logan	$54^{0}27'$	$96^{0}10'$	1,320	2	2.52	2.39 - 2.65
Loon River	$56^{0}20'$	$101^{0}44'$	1,036	1	3.57	
MacBride	$56^{0}52'$	$99^{0}57'$	565	1	6.04	
Max	$54^{0}33'$	$95^{0}58'$	1,810	4	3.43	2.20 - 5.35

Appendix VII. (Cont'd).

Lake	Location		Area	No. of years	Production	Range of Production
	Latitude	Longitude	ha	fished	kg ha^{-1}yr^{-1}	kg ha^{-1}yr^{-1}
McKnight	56°03'	101°08'	4,662	3	1.93	0.71 - 3.68
Matheson group	56°24'	101°47'	1,210	2	1.79	1.13 - 2.44
Molson	54°12'	96°45'	37,169	2	0.09	0.06 - 0.12
Moody	55°06'	100°43'	484	2	5.67	2.42 - 8.92
Moose(East Arm)	53°55'	99°45'	57,370	4	0.60	0.35 - 0.83
Moose(North Arm)	54°05'	100°10'	52,630	5	1.10	0.94 - 1.25
Moose(Pickerel)	53°50'	100°00'	63,602	5	3.26	3.04 - 3.55
Morin	55°36'	101°24'	2,016	1	1.41	
Mynarski	56°10'	99°10'	3,105	2	4.30	3.82 - 4.73
Naosap	54°51'	101°24'	2,298	1	0.43	
Natawahunan	55°42'	07°09'	4,516	4	2.60	1.19 - 4.01
Notigi	55°57'	99°18'	1,970	3	2.68	1.26 - 5.08
Opachunau	56°44'	99°37'	7,957	5	2.89	1.37 - 3.82
Oskatik	54°43'	101°32'	605	2	6.05	4.61 - 7.49
Oxford	54°51'	95°37'	33,929	5	0.92	0.40 - 1.49
Paint	55°28'	95°57'	10,023	2	0.20	0.08 - 0.33
Pakwa	54°51'	98°53'	3,978	5	3.71	2.24 - 4.64
Partridge Crop	55°38'	97°89'	7,389	5	0.87	0.41 - 1.48
Pikwitonei	55°33'	97°09'	2,569	5	2.10	1.60 - 3.11
Pipestone	54°31'	97°38'	4,839	3	4.25	2.97 - 5.41
Playgreen	54°16'	97°58'	68,896	5	3.67	3.36 - 4.27
Rat East	54°40'	95°30'	2,742	3	8.58	6.66 -10.25
Rat West	56°10'	99°40'	7,128	1	2.01	

Appendix VII. (Cont'd).

Lake	Location		Area	No. of years	Production	Range of Production
	Latitude	Longitude	ha	fished	kg $ha^{-1}yr^{-1}$	kg $ha^{-1}yr^{-1}$
Red Sucker	$54^{0}09'$	$93^{0}40'$	23,041	5	1.20	0.64 - 1.61
Reed	$54^{0}38'$	$100^{0}30'$	18,980	1	0.30	
Robinson	$54^{0}23'$	$96^{0}23'$	1,694	2	2.28	1.70 - 2.86
Rocky	$54^{0}10'$	$101^{0}10'$	11,687	5**	0.23	0.03 - 0.53
Russell	$56^{0}15'$	$101^{0}30'$	12,888	4	0.38	0.26 - 0.49
Rusty	$56^{0}34'$	$99^{0}37'$	1,347	4	4.17	4.02 - 4.46
Sabomin	$55^{0}18'$	$97^{0}15'$	1,450	5	2.31	1.04 - 3.81
Seller	$55^{0}00'$	$94^{0}30'$	5,363	1	1.09	
Semmens	$55^{0}02'$	$94^{0}12'$	7,904	1	5.54	
Setting	$55^{0}00'$	$98^{0}38'$	13, 427	5	2.65	1.14 - 3.64
Sharpe	$54^{0}24'$	$93^{0}30'$	9,275	4	3.48	2.68 - 4.16
Simonhouse	$54^{0}33'$	$101^{0}10'$	8,198	1**	0.24	
Simpson, Swede, Ellystan	$56^{0}52'$	$100^{0}25'$	370	1	7.85	
Sipiwesk	$55^{0}05'$	$97^{0}35'$	39,327	5	1.17	0.20 - 2.17
Sisipuk	$55^{0}45'$	$101^{0}50'$	16,058	4	1.47	0.23 - 2.69
Suwannee	$56^{0}03'$	$100^{0}10'$	4,973	4	1.89	0.13 - 3.58
Solomon	$54^{0}48'$	$97^{0}45'$	780	3	7.80	4.35 -12.63
Split	$56^{0}08'$	$96^{0}15'$	28,387	4	0.96	0.69 - 1.18
Stag	$56^{0}30'$	$100^{0}25'$	1,895	3	1.83	1.37 - 2.70
Stephens	$56^{0}30'$	$95^{0}15'$	2,177	3	0.99	0.89 - 1.10
Stevenson - Pelican	$53^{0}55'$	$96^{0}09'$	13,732	5	3.80	3.43 - 4.10
Story	$56^{0}41'$	$101^{0}04'$	605	1	4.65	
Stuport	$55^{0}37'$	$94^{0}03'$	3,024	2	2.81	2.76 - 2.86
Talbot	$54^{0}00'$	$99^{0}55'$	19,063	4	0.50	0.25 - 0.96

Appendix VII. (Cont'd).

Lake	**Location**		**Area**	**No. of years**	**Production**	**Range of Production**
	Latitude	Longitude	ha	fished	kg $ha^{-1} yr^{-1}$	kg $ha^{-1} yr^{-1}$
Touchwood	$54^{0}29'$	$95^{0}00'$	8,267	5	2.64	2.17 - 2.98
Uhlman	$56^{0}41'$	$98^{0}23'$	4,921	3	1.01	0.14 - 2.20
Utik	$55^{0}16'$	$96^{0}00'$	17,239	5	1.67	0.64 - 2.53
Walker	$54^{0}42'$	$96^{0}57'$	13,755	4	2.46	1.09 - 4.41
Wapisu	$55^{0}47'$	$99^{0}11'$	5,180	1	1.75	
War	$55^{0}53'$	$95^{0}39'$	995	2	4.36	3.73 - 4.99
Wass	$53^{0}34'$	$95^{0}24'$	3,065	3	4.21**	3.27 - 5.56
Wedge	$54^{0}40'$	$101^{0}05'$	848	1	2.49	
Wekusko	$56^{0}30'$	$96^{0}20'$	22,180	5	3.65**	3.10 - 4.54
White Rabbit	$54^{0}59'$	$97^{0}20'$	1,824	4	2.92**	2.65 - 3.16
Wilkins(Cub)	$55^{0}09'$	$96^{0}30'$	1,936	1	1.63	
William	$53^{0}54'$	$99^{0}21'$	11,893	5	4.37**	2.69 - 6.16
Wintering	$55^{0}23'$	$97^{0}43'$	10,609	4	1.22**	0.19 - 1.33
Witchai	$55^{0}57'$	$96^{0}51'$	3,674	5	2.78	1.61 - 3.41
Woosey - Morgan	$54^{0}47'$	$100^{0}16'$	1,943	4	2.55	1.27 - 4.08
Wuskwatim	$55^{0}32'$	$98^{0}32'$	6,465	3	2.55	2.14 - 2.88
Yawningstone	$54^{0}21'$	$100^{0}51'$	1,160	4	1.99	0.19 - 4.36

** experimental netting

Appendix VIII. Actual fish yields from lakes commercially fished in the south region in Manitoba, 1976 - 1980.

Lake	**Location**		**Area**	**No. of years**	**Production**	**Range of Production**
	Latitude	**Longitude**	**ha**	**fished**	**kg ha^{-1}yr^{-1}**	**kg ha^{-1}yr^{-1}**
Armit	$52^{0}33'$	$101^{0}15'$	2,540	1**	0.53	
Dauphin	$51^{0}10'$	$99^{0}50'$	51,930	5	0.88	0.53 - 1.24
Lonely	$51^{0}10'$	$99^{0}05'$		5		
Pelican	$52^{0}28'$	$100^{0}20'$	17,710	5	1.95	1.15 - 2.71
Red Deer	$52^{0}56'$	$101^{0}20'$	25,230	5	1.31	0.72 - 1.76
Swan	$52^{0}30'$	$100^{0}45'$	13,620	5	2.23	1.02 - 3.43
St. Martin	$51^{0}40'$	$98^{0}20'$	30,090	5	11.64	7.16 -17.76
Waterhen	$52^{0}10'$	$99^{0}25'$	21,770	5	3.95	2.38 - 4.56

** experimental fishing

Appendix IX. Species composition breakdown between the preferred species (whitefish, walleye, sauger, pike and lake trout) and non-quota species* caught in Manitoba waters.

Area	Preferred species		Other species		Total
	no/yr	%	no/yr	%	
Lake Winnipeg[1]	4,498	4	4,798	52	9,296
Lake Winnipegosis[2]	1,651	47	1,899	53	3,550
Lake Manitoba[3]	1,685	57	1,602	49	3,287
Northern[4]	21,706	46	25,002	54	46,708
Southern[4]	677	34	1,311	66	1,988
TOTAL	30,217	47	34,612	53	64,829

*Non-quota species are listed in text.

[1] Average of 1979 and 1980 Lake Winnipeg fish stock assessment programs by Lysack (1980 and 1981).

[2] Average of 1978-1981 experimental netting (3" mesh only). From J. Edwards, pers. comm.

[3] Average of 1978-1982 spring and fall experimental catches. Mesh sizes mainly used were 3", 3¼", 3 3/4", 4" and 4½". From K. Campbell, pers. comm.

[4] Average of experimental netting catches reported in lake survey reports. Lake survey reports are listed in Appendix I.

Appendix X. Domestic consumption of fish by various northern communities which have been surveyed.

Community	Annual per capita consumption (kg)	Source document
Pukatawagan	37	1
South Indian Lake	24	"
Nelson House	12	"
Brochet	12	"
Little Grand Rapids	36	"
Pauingassi	35	"
St. Therese	36	"
Garden Hill	23	"
Wasagamach	36	"
Red Sucker	23	"
Oxford House	36	"
Gods Lake	38	"
Shamattawa	22	"
Granville Lake	22	"
Cross Lake	26	"
	46	17

Appendix XI. Data on sport fishing licence sales in Manitoba between 1955 - 1980.

Year	Manitoba population	Resident angling licences	Percent of res. licences of Man. population	Non-resident angling licences	Non-resident 3-day permit	Percent 3-day permit/seasonal non-resident	Total non-resident angling licences	Percent of non-resident/resident licences	Total angling licence sales	Percent non-resident/total angling sales
1950		559*		6,226			6,226		6,785	
1951	776,500	921*		8,411			8,411		9,332	
1952		538*		8,456			8,456		8,994	
1953		428*		7,765			7,765		8,193	
1954		503*		8,543			8,543		9,046	
1955		56,595		10,072			10,072	17.8	67,031	15.0
1956	850,000	60,911	7.2	10,615			10,415	17.1	71,426	14.6
1957		75,163		12,392			12,392	16.5	87,455	14.2
1958		83,171		12,992			12,992	15.6	96,163	13.5
1959		85,182		12,861			12,861	15.1	98,043	13.1
1960		90,726		13,532			13,532	14.9	104,258	13.0
1961	921,700	87,475	9.5	13,731			13,731	15.7	101,206	13.6
1962		91,725		13,225			13,225	14.4	104,950	12.6
1963		78,760		15,949			15,949	20.3	94,709	16.8
1964		79,958		15,080			15,080	18.9	95,038	15.9
1965		82,733		15,346			15,346	18.5	98,079	15.6
1966	963,100	87,187	9.1	17,438			17,438	20.0	104,625	16.7
1967		91,269		19,156			19,156	21.0	110,425	17.3
1968		96,896		22,956			22,956	23.2	119,852	19.2
1969		104,687		21,490	4,709	21.9	26,199	25.0	130,886	20.0
1970		90,979		20,989	5,414	25.8	26,403	29.0	117,382	22.5
1971	988,200	108,331	11.0	23,644	6,302	26.6	29,996	27.7	138,327	21.7
1972	991,200	117,621	11.9	24,423	7,501	30.7	31,926	27.1	149,545	21.3
1973	996,200	127,440	12.8	26,217	7,871	30.0	34,088	26.7	161,528	21.1
1974	1,007,500	137,492	13.6	24,306	7,402	30.5	31,708	23.1	169,218	18.7
1975	1,013,600	142,226	14.0	27,435	8,423	30.7	35,858	25.2	178,084	20.1
1976	1,021,500	150,020	14.7	29,475	9,845	33.4	39,320	26.2	189,340	20.8
1977	1,029,000	148,289	14.4	28,363	9,175	32.3	37,538	25.3	185,827	20.2
1978	1,031,600	156,553	15.2	29,929	10,918	36.5	40,847	26.1	197,400	20.7
1979	1,029,600	155,790	15.1	31,029	9,590	30.9	40,619	26.1	196,409	20.7
1980	1,025,600	159,584	15.6	32,353	8,658	26.8	41,011	25.7	200,595	20.4

* Resident anglers only required permits for winter fishing, consequently, information from 1955 - 1980 was only used.